

TRANSFORMING AMERICA'S AIR TRAVEL

HEARING BEFORE THE SUBCOMMITTEE ON SPACE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY HOUSE OF REPRESENTATIVES ONE HUNDRED FOURTEENTH CONGRESS

FIRST SESSION

June 11, 2015

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TRANSFORMING AMERICA'S AIR TRAVEL

THURSDAY, JUNE 11, 2015

HOUSE OF REPRESENTATIVES,
SUBCOMMITTEE ON SPACE
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY,
Washington, D.C.

The Subcommittee met, pursuant to call, at 9:02 a.m., in Room 2318 of the Rayburn House Office Building, Hon. Brian Babin [Chairman of the Subcommittee] presiding.

LAMAR S. SMITH, Texas
CHAIRMAN

EDDIE BERNICE JOHNSON, Texas
RANKING MEMBER

Congress of the United States
House of Representatives
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
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Subcommittee on Space

Transforming America's Air Travel

Thursday, June 11, 2015
9:00 a.m. to 11:00 a.m.
2318 Rayburn House Office Building

Witnesses

Dr. Jaiwon Shin, Associate Administrator, Aeronautics Research Mission Directorate, NASA;
Member, FAA Research and Development Advisory Committee

Mr. Dennis Filler, Director, William J. Hughes Technical Center, FAA

Mr. William Leber, Co-Chair, Committee to Review the Federal Aviation Administration
Research Plan on Certification of New Technologies into the National Airspace System; Vice-
President, Air Traffic Innovations, PASSUR Aerospace

Dr. R. John Hansman, T. Wilson Professor of Aeronautics & Astronautics, Massachusetts
Institute of Technology; Director, MIT International Center for Air Transportation,
Massachusetts Institute of Technology; Chair, FAA Research and Development Advisory
Committee

Dr. Greg Hyslop, Senior Member, American Institute for Aeronautics and Astronautics; Vice
President and General Manager, Boeing Research & Technology, the Boeing Company; Chief
Engineer, Engineering, Operations & Technology, the Boeing Company

**U.S. HOUSE OF REPRESENTATIVES
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
SUBCOMMITTEE ON SPACE**

Transforming America's Air Travel

June 11, 2015

9:00 a.m.

2318 Rayburn House Office Building

Purpose

The purpose of this hearing is to review the current state of civil aeronautics research and inform the Committee's consideration of the Federal Aviation Administration (FAA) Reauthorization.

Witnesses

- Dr. Jaiwon Shin, Associate Administrator, Aeronautics Mission Directorate, NASA; and Member FAA Research and Development Advisory Committee.
- Mr. Dennis Filler, Director, William J. Hughes Technical Center, FAA.
- Mr. William Leber, Chair, National Research Council report titled "Transformation in the Air – A Review of the FAA Research Plan;" and Vice President, Air Traffic Innovations, PASSUR Aerospace.
- Dr. R. John Hansman, T. Wilson Professor of Aeronautics & Astronautics; Director, MIT International Center for Air Transportation, Massachusetts Institute of Technology; and Chair, FAA Research and Development Advisory Committee.
- Dr. Greg Hyslop, Senior Member, American Institute for Aeronautics and Astronautics; Vice President and General Manager, Boeing Research & Technology; Chief Engineer, Engineering, Operations & Technology, the Boeing Company.

Background

The FAA and the National Aeronautics and Space Administration (NASA) conduct federal civil aeronautics research and development (R&D). The FAA conducts, coordinates, and supports domestic and international research and development of aviation related products and services, including the Next Generation Air Transportation System (NextGen).¹ NASA conducts fundamental and applied aeronautics research.² NASA's current activities are focused in four program areas: advanced air vehicles program (AAVP), airspace operations and safety program (AOSP), integrated aviation systems program (IASP), and the transformative aeronautics concepts program (TACP).

¹ See 49 U.S.C. §40501 et al. Accessed at <http://www.gpo.gov/fdsys/pkg/USCODE-2011-title49/html/USCODE-2011-title49.htm>

² See 51 U.S.C. §40101 et al. Accessed at <http://www.gpo.gov/fdsys/pkg/USCODE-2011-title51/html/USCODE-2011-title51.htm>

The FAA was last reauthorized in 2012, under the *FAA Modernization and Reform Act of 2012*.³ This authorization was for fiscal years (FY) 2012-2015. FAA research and development activities are a component of the broader FAA reauthorization effort.

NASA was last authorized in 2010, under the *National Aeronautics and Space Administration Authorization Act of 2010*. This authorization was for FY2011-2013. The House of Representatives authorized NASA aeronautics research as part of the overall NASA authorization in 2014⁴ and 2015⁵, but the legislation awaits consideration by the Senate.

FAA Research, Engineering, & Development (R,E&D) Budget Request

Budget Authority (\$ in millions)	FY15 Enacted	FY16 Request
Safety	91.019	96.623
Fire Research and Safety	6.000	6.643
Propulsion and Fuel Systems	2.000	3.034
Advanced Materials/Structural Safety	2.909	3.625
Aircraft Icing/Digital System Safety	5.500	6.920
Continued Airworthiness	9.619	8.987
Aircraft Catastrophic Failure Prevention Research	1.500	1.433
Flightdeck/Maintenance/System Integration Human Factors	6.000	9.947
System Safety Management	7.970	6.063
ATC/Technical Operations Human Factors	5.400	5.995
Aeromedical Research	8.300	10.255
Weather Program	14.847	18.253
Unmanned Aircraft Systems (UAS) Research	14.974	9.635
NextGen – Alt Jet Fuel for General Aviation	6.000	5.833
Economic Competitiveness	22.286	24.671
NextGen - Wake Turbulence	8.541	8.680
NextGen - Air Ground Integration Human Factors	9.697	8.875
NextGen Weather Tech in the Cockpit	4.048	4.116
Commercial Space	--	3.000
Environmental Sustainability	37.935	38.884
Environment and Energy	14.921	15.061
Environmental Research – Aircraft Tech, Fuels, and Metrics	23.014	23.823
Mission Support	5.510	5.822
System Planning and Resource Management	2.100	2.377
William J. Hughes Technical Center	3.410	3.445
Total	156.750	166.000

³ P.L. 112-95

⁴ See <http://science.house.gov/press-release/house-passes-bipartisan-nasa-authorization-act>

⁵ See <https://science.house.gov/press-release/house-passes-bipartisan-nasa-bill>

The FAA supports a range of research activities from materials and aeromedical research to the development of new products, services, and procedures. FAA's FY16 budget request includes \$166 million for research, engineering and development (R,E&D). This is an increase of \$9.3 million (6 percent) above the FY2015 enacted level of \$156.75 million. FAA's R,E&D research is categorized into four areas: Safety, Economic Competitiveness, Environmental Sustainability, and Mission Support.

Noteworthy changes include an increase in Propulsion and Fuel Systems (\$1.034 million); an increase for Aircraft Icing / Digital System Safety (\$1.420 million); an increase in Flightdeck / Maintenance / System Integration Human Factors (\$3.947 million); a decrease to System Safety Management (\$1.907 million); an increase to Aeromedical Research (\$1.955 million); an increase to the Weather Program (\$3.406 million); a decrease to Unmanned Aircraft Systems Research (\$5.339 million); and an increase to Commercial Space (\$3 million).

In addition to R,E&D, the FAA FY16 budget request includes \$198 million for research and development funding under the Facilities and Equipment (F&E) account and \$46 million under the Grants-In-Aid for Airports (AIP).⁶

FAA NextGen R,E&D Budget Request

Budget Authority (\$ in millions)	FY15 Enacted	FY16 Request
Alternative Fuel for General Aviation	6.000	5.833
Wake Turbulence	8.541	8.680
Air Ground Integration Human Factors	9.697	8.875
Weather Tech in the Cockpit	4.048	4.116
Environmental Research – Aircraft Tech, Fuels, and Metrics	23.014	23.823
Unmanned Aircraft Systems Research [†]		9.635
Total	51.300	60.962

[†] Note – FY16 is the first year that UAS has been included into the NextGen program.

The FY16 R,E&D budget requests \$61 million specifically for NextGen, an increase of \$9.7 million over FY2015 enacted level. This is largely a result of including UAS research in the NextGen Program for the first time.

Notably, environmental research and alternative fuel research accounts for nearly half of all NextGen R,E&D funding.

⁶ These activities are not listed in the following chart.

NASA Aeronautics Research Budget Request

Budget Authority (\$ in millions)	Actual 2014	Enacted 2015†	Request 2016
Airspace Operations and Safety Program	-	154	142.4
Advanced Air Vehicles Program	-	248.1	240.9
Integrated Aviation Systems Program	-	150	96.0
Transformative Aeronautics Concepts Program	-	97.4	92.1
Aviation Safety	80.0	-	-
Airspace Systems	91.8	-	-
Fundamental Aeronautics	168.0	-	-
Aeronautics Test	77.0	-	-
Integrated Systems Research	126.5	-	-
Aeronautics Strategy & Management	22.7	-	-
Total	566.0	650.5	571.4

†Reflects FY15 Operations Plan submitted to Congress on March 6, 2015, which reduced the Advanced Air Vehicles program by \$500,000 from enacted level.

NASA's Aeronautics Research Mission Directorate (ARMD) conducts aeronautics research to improve aviation safety, efficiency, and air traffic management, and to develop game-changing technology to facilitate the continued growth of the U.S. aviation industry. The FY16 budget request for ARMD is \$571.4 million, a 12 percent decrease (\$79.6 million) from the \$651 million included in the FY15 appropriations act.

In FY16, NASA will focus on six strategic "thrusters." These include:

- 1) Safe, Efficient Growth in Global Operations
 - Enable full NextGen and develop technologies to substantially reduce aircraft safety risks;
- 2) Innovation in Commercial Supersonic Aircraft
 - Achieve a low-boom standard;
- 3) Ultra-Efficient Commercial Vehicles
 - Pioneer technologies for big leaps in efficiency and environmental performance;
- 4) Transition to Low-Carbon Propulsion
 - Characterize drop-in alternative fuels and pioneer low-carbon propulsion technology;
- 5) Real-Time System-Wide Safety Assurances
 - Develop an integrated prototype of a real-time safety monitoring and assurance system;
- 6) Assured Autonomy for Aviation Transformation
 - Develop high impact aviation autonomy applications.

National Research Council

Transformation in the Air—A Review of the FAA's Certification Research Plan

The National Research Council (NRC) issued a report this week titled *Transformation in the Air – A Review of the FAA's Certification Research Plan*. The FAA Modernization and Reform Act

of 2012 required the FAA to develop a research plan for the certification of new technologies into the NAS and have the NRC review that plan. In response to this statutory directive, the NRC empaneled a study to assess the FAA's plan for research on methods and procedures to improve both confidence in and the timeliness of certification of new technologies for their introduction into the National Airspace System (NAS). The NRC determined that "the plan lack detail and specificity and does not provide an effective guide to FAA research of the 5-year term required by the act."⁷ The committee concluded "it is more of a high-level task plan for incrementally developing over the next 5 years than the detailed research plan that the FAA will actually need" and that "the plan does not meet the requirements of the authorizing legislation." The report went on to state that, "[w]hereas the plan restates the language from the FAA Modernization and Reform Act of 2012, it lacks the specificity required to generate actionable objectives. It is more of a high-level task plan for incrementally developing over the next 5 years the detailed research plan that the FAA will actually need."⁸

The committee recommended that "in order to improve confidence in and timeliness of the certification of new technologies and the approval new operations they enable in the NAS, the FAA should create a comprehensive research plan that results in a documented approach that provides the full context for its certification and implementation of Next Gen, including both ground and air elements, and the plan's relationship to the other activities and procedures required for certification and implementation into the NAS."⁹ The committee concluded that "future FAA research plans, when properly assembled and executed, can play a valuable role in guiding the FAA and stakeholders and explaining progress in certifying new technologies into the NAS. The committee provided a number of recommendations to the FAA."¹⁰

A Review of the Next Generation Transportation System: Implications and Importance of System Architecture

The NRC issued a report last month titled "A Review of the Next Generation Transportation System: Implications and Importance of System Architecture." This review focused on enterprise architecture, software development approaches, and safety and human factors.

The report found that "The original vision for NextGen is not what is being implemented today. Instead, NextGen today primarily emphasizes replacing and modernizing aging equipment and systems."¹¹ The NRC continued by stating that "[t]he Federal Aviation Administration (FAA) should create an architecture community that can produce and evolve a system architecture and should also strengthen its workforce in systems engineering and integration, digital communications, and cybersecurity to increase the likelihood it will succeed in developing the architecture and managing the implementation of the systems it describes." Finally, the NRC concluded that "NextGen and its system architecture should be developed to cope with change. Two newly important areas, cybersecurity and unmanned vehicles, make this need particularly resonant. Human factors will also play an important role in NextGen and the NAS as each evolves. Finally, regarding anticipated costs and benefits, airlines are not motivated to spend

⁷ *Id.* at 2

⁸ *Id.* at 2

⁹ *Id.* at 3

¹⁰ *Id.* at 3

¹¹ "A Review of the Next Generation Air Transportation System: Implications and Importance of System Architecture," National Research Council, May 2015

money on equipment and training for NextGen because they do not receive most of the benefits directly and because of implementation schedule uncertainties. The rest of this summary elaborates these and related observations in more detail and highlights several of the committee's findings and recommendations in bold."

Government Accountability Office

Air Traffic Control: FAA Needs a More Comprehensive Approach to Address Cybersecurity As Agency Transitions to NextGen

GAO issued a report last April that reviewed FAA's cybersecurity efforts. The GAO found that, "[a]s the agency transitions to the Next Generation Air Transportation System (NextGen), the Federal Aviation Administration (FAA) faces cybersecurity challenges in at least three areas: (1) protecting air-traffic control (ATC) information systems, (2) protecting aircraft avionics used to operate and guide aircraft, and (3) clarifying cybersecurity roles and responsibilities among multiple FAA offices.

As GAO reported in January 2015, FAA has taken steps to protect its ATC systems from cyber-based threats; however, significant security-control weaknesses remain that threaten the agency's ability to ensure the safe and uninterrupted operation of the national airspace system. FAA has agreed to address these weaknesses. Nevertheless, FAA will continue to be challenged in protecting ATC systems because it has not developed a cybersecurity threat model. NIST guidance, as well as experts GAO consulted, recommend such modeling to identify potential threats to information systems, and as a basis for aligning cybersecurity efforts and limited resources. While FAA has taken some steps toward developing such a model, it has no plans to produce one and has not assessed the funding or time that would be needed to do so. Without such a model, FAA may not be allocating resources properly to guard against the most significant cybersecurity threats.

Modern aircraft are increasingly connected to the Internet. This interconnectedness can potentially provide unauthorized remote access to aircraft avionics systems. As part of the aircraft certification process, FAA's Office of Safety (AVS) currently certifies new interconnected systems through rules for specific aircraft and has started reviewing rules for certifying the cybersecurity of all new aircraft systems.

FAA is making strides to address the challenge of clarifying cybersecurity roles and responsibilities among multiple FAA offices, such as creating a Cyber Security Steering Committee (the Committee) to oversee information security. However, AVS is not represented on the Committee but can be included on an ad-hoc advisory basis. Not including AVS as a full member could hinder FAA's efforts to develop a coordinated, holistic, agency-wide approach to cybersecurity.

FAA's acquisition management process generally aligned with federal guidelines for incorporating requirements for cybersecurity controls in its acquisition of NextGen programs. For example, the process included the six major information-technology and risk-management activities as described by NIST. Timely implementation of some of these activities could have been improved based on their importance to NextGen, cost, and deployment status. The Surveillance and Broadcast Services Subsystem (SBSS)—which enables satellite guidance of

aircraft and is currently deployed in parts of the nation—has not adopted all of the April 2013 changes to NIST security controls, such as intrusion detection improvements, although the Office of Management and Budget guidance states that deployed systems must adopt changes within one year. Systems with weaknesses that could be exploited by adversaries may be at increased risk if relevant controls are not implemented.”¹²

¹² “Aviation Security: FAA Needs a More Comprehensive Approach to Address Cybersecurity As the Agency Transitions to NextGen,” Government Accountability Office, April 2015.

Chairman BABIN. Good morning. The Subcommittee on Space will come to order.

Without objection, the Chair is authorized to declare recesses of the Committee at any time. Without objection, the Chairman of the Transportation and Infrastructure Committee's Subcommittee on Aviation, Mr. LoBiondo, will be allowed to participate in today's hearing.

And welcome to today's hearing titled "Transforming America's Air Travel." I recognize myself for five minutes for an opening statement.

Before we begin this morning, I want to thank Chairman Lamar Smith and my colleagues for the opportunity to serve as the Chairman of the Space Subcommittee. It is truly an honor and a privilege. And my district includes the Johnson Space Center and many of National Aeronautics and Space Administration's astronauts, scientists, engineers, technicians, and contractors, and they call the 36th district of Texas home. Because of this, I am keenly aware of the opportunities and challenges that face NASA and our aerospace sector. I look forward to working with Chairman Smith, Ranking Member Johnson, Ranking Member Edwards, and this Congress.

I also want to thank Chairman Palazzo for his leadership during what has been a very busy spring for the Space Subcommittee. Thankfully, he is moving to the Appropriations Subcommittee on Commerce, Science, and Justice which still has jurisdiction over NASA spending, so I am certain that we will stay in touch.

This year marks the 100th anniversary of the founding of the National Advisory Committee for Aeronautics, also known as NACA. Founded in 1915 to supervise and direct the scientific study of the problems of flight with a view to their practical solution, NACA was ultimately incorporated into NASA when Congress passed the National Aeronautics and Space Act of 1958. That same year, Congress also established the Federal Aviation Administration's predecessor, the Federal Aviation Agency. NACA's legacy of civilian aeronautics and aviation research and development is now carried out by NASA and FAA.

The aeronautics research carried out by these agencies is vital to our nation's prosperity. Aviation accounts for \$1.5 trillion in economic activity and a \$78.3 billion positive trade balance. Civil and general aviation is responsible for 11.8 million jobs in the U.S. and generates 5.4 percent of our gross domestic product. Put simply, aviation is one of the pillars of our economy.

And while we currently enjoy the benefits of our nation's early investments in aeronautics R&D, other nations are now attempting to challenge our leadership. This is particularly troubling when the largest growth sector is not here in the United States but in Asia. In order to maintain our leadership, we must strategically prioritize our government investments, provide a competitive environment for industry, and coordinate and clearly define public and private sector efforts to maximize efficiencies and minimize duplication that may crowd out investment. If we are successful in these efforts, the potential aerospace breakthroughs in the coming decades are very, very promising.

Advances in hypersonic flight could revolutionize the aerospace sector. Continued research into supersonics and air traffic manage-

ment could greatly reduce flight times. Structural and material research stands to improve safety and save lives. Unmanned aircraft systems, or UAS, research and development could benefit agriculture, search and rescue, fighting forest fires, mapping and surveying, and even package delivery.

In order to realize these benefits, we must be ever vigilant. NASA and FAA will have to ensure that the research they support does not duplicate private sector investments. For instance, industry has a considerable incentive to develop safer, more reliable, and more efficient aircraft. Federal intervention and support should be limited to high-risk, high-reward research that the private sector cannot or will not do on their own. Without such prioritization, valuable resources risk being diluted among disparate tasks. This requires a great deal of coordination between NASA and the FAA.

Many of the activities that we will be discussing today are conducted by both these agencies. In 2003, Congress established the Joint Planning Development Office, or JPDO, to coordinate efforts between NASA, FAA, and other agencies to develop the Next Generation Air Transportation System, known as NextGen. JPDO functions were recently rolled into the NextGen program office, but the issue highlights an overarching theme that Congress will have to monitor. As budgets tighten, NASA should not be used as a piggy bank for other agency requirements.

As many have pointed out in the past, the first A in NASA is aeronautics. But we need to be clear: aeronautics is more than just air traffic management, aviation efficiency, and green fuels. NASA has a long and proud tradition of pushing the boundaries of the possible, a legacy that it should ensure continues into the future. Similarly, we need to ensure that FAA is focused on safety and efficiency. That clearly requires coordination, but hopefully will not cause wasteful duplication or sacrifice the cutting-edge breakthroughs we're used to.

Aerospace and aviation research promise many benefits, but not without challenges. NextGen continues to lack clearly defined cost, schedule, and performance parameters. Last year, the FAA Inspector General testified that the initial cost estimate of \$40 billion split between federal and private sector investment could double or even triple, and that implementation could take an additional decade. This is unacceptable. Congress either needs better baselines and metrics to track progress, or a different plan. In the interim, I fear that valuable R&D funding, the very seed corn of future prosperity, is being used to simply maintain World War II-era systems.

The challenges are also near term. While Congress waits for NextGen details, reports of potential cyber vulnerabilities to aircraft and NextGen systems proliferate in the press. While recent allegations may be overstated, respected and knowledgeable experts, such as the Government Accountability Office and the National Research Council, have warned that cybersecurity should play a more prominent role in NextGen development.

I want to conclude by thanking our witnesses for being here today to discuss aeronautics and aviation research. This highly esteemed panel will certainly inform the Committee's consideration of

the Research, Engineering, and Development activities at FAA. I look forward to their testimony and I appreciate their participation. [The prepared statement of Chairman Babin follows:]

PREPARED STATEMENT OF SUBCOMMITTEE ON SPACE
CHAIRMAN BRIAN BABIN

Before we begin this morning, I want to thank Chairman Smith and my colleagues for the opportunity to serve as the Chairman of the Space Subcommittee. It is truly an honor and a privilege. My district includes the Johnson Space Center and many of National Aeronautics and Space Administration's (NASA) astronauts, scientists, engineers, technicians, and contractors call the 36th district of Texas home. Because of this, I am keenly aware of the opportunities and challenges facing NASA and the aerospace sector. I look forward to working with Chairman Smith, Ranking Member Johnson, and Ranking Member Edwards this Congress. I also want to thank Chairman Palazzo for his leadership during what has been a very busy spring for the Space Subcommittee. Thankfully he is moving to the Appropriations Subcommittee on Commerce, Science, and Justice which has jurisdiction over NASA spending, so I am certain we will stay in touch.

This year marks the 100th anniversary of the founding of the National Advisory Committee for Aeronautics, or "NACA." Founded in 1915 to "supervise and direct the scientific study of the problems of flight with a view to their practical solution," NACA was ultimately incorporated into NASA when Congress passed the National Aeronautics and Space Act of 1958. That same year, Congress also established the Federal Aviation Administration's (FAA) predecessor, the Federal Aviation Agency. NACA's legacy of civilian aeronautics and aviation research and development (R&D) is now carried out by NASA and FAA.

The aeronautics research carried out by these agencies is vital to our nation's prosperity. Aviation accounts for \$1.5 trillion in economic activity and a \$78.3 billion positive trade balance. Civil and general aviation is responsible for 11.8 million jobs in the U.S. and generates 5.4 percent of our gross domestic product. Put simply, aviation is one of the pillars of our economy.

While we currently enjoy the benefits of our nation's early investments in aeronautics R&D, other nations are now attempting to challenge our leadership. This is particularly troubling when the largest growth sector is not here in the U.S., but in Asia. In order to maintain our leadership, we must strategically prioritize our government investments, provide a competitive environment for industry, and coordinate and clearly define public and private sector efforts to maximize efficiencies and minimize duplication that may crowd-out investment.

If we are successful in these efforts, the potential aerospace breakthroughs in the coming decades are promising. Advances in hypersonic flight could revolutionize the aerospace sector. Continued research into supersonics and air traffic management could greatly reduce flight times. Structural and material research stands to improve safety and save lives. Unmanned Aircraft Systems (UAS) R&D could benefit agriculture, search and rescue, fighting forest fires, mapping and surveying, and even package delivery.

In order to realize these benefits, we must be ever-vigilant. NASA and FAA will have to ensure that the research they support does not duplicate private sector investments. For instance, industry has a considerable incentive to develop safer, more reliable, and more efficient aircraft. Federal intervention and support should be limited to high-risk, high-reward research that the private sector cannot or will not do on their own. Without such prioritization, valuable resources risk being diluted among disparate tasks. This requires a great deal of coordination between NASA and the FAA. Many of the activities we will be discussing today are conducted by both these agencies.

In 2003, Congress established the Joint Planning Development Office (JPDO) to coordinate efforts between NASA, FAA, and other agencies to develop the Next Generation Air Transportation System (NextGen). JPDO functions were recently rolled into the NextGen program office, but the issue highlights an overarching theme that Congress will have to monitor. As budgets tighten, NASA should not be used as a piggy-bank for other agency requirements. As many have pointed out in the past, the first "A" in NASA is "aeronautics." But we need to be clear—aeronautics is more than just air traffic management, aviation efficiency, and green fuels. NASA has a long and proud tradition of pushing the boundaries of the possible, a legacy it should ensure continues into the future. Similarly, we need to ensure FAA is fo-

cused on safety and efficiency. That clearly requires coordination, but hopefully it will not cause wasteful duplication or sacrifice cutting-edge breakthroughs.

Aerospace and aviation research promise many benefits, but not without challenges. NextGen continues to lack clearly defined cost, schedule, and performance parameters. Last year, the FAA Inspector General testified that the initial cost estimate of \$40 billion split between federal and private sector investment could double or triple, and that implementation could take an additional decade. This is unacceptable. Congress either needs better baselines and metrics to track progress, or a different plan. In the interim, I fear that valuable R&D funding, the seed corn of future prosperity, is being used to simply maintain World War II-era systems.

The challenges are also near-term. While Congress waits for NextGen details, reports of potential cyber vulnerabilities to aircraft and NextGen systems proliferate in the press. While recent allegations may be overstated, respected and knowledgeable experts, such as the Government Accountability Office and the National Research Council, have warned that cyber security should play a more prominent role in NextGen development.

I want to conclude by thanking our witnesses for being here today to discuss aeronautics and aviation research. This highly esteemed panel will certainly inform the Committee's consideration of the Research, Engineering, and Development activities at FAA. I look forward to their testimony and appreciate their participation.

Chairman BABIN. I now recognize the Ranking Member, the gentlewoman from Maryland, for an opening statement.

Ms. EDWARDS. Thank you very much, Mr. Chairman, and good morning, and welcome also to our panel of witnesses. Also, welcome to my colleague, Mr. LoBiondo from the Transportation and Infrastructure Committee. I appreciate your participation today.

Mr. Chairman, I really want to thank you for calling this hearing to review the current state of U.S. civil aeronautics research and development. But before I begin, I also want to congratulate you on your Chairmanship of this Subcommittee. I had a wonderful, what started out as a working relationship with former Chairman Palazzo and quickly became a friendship, and I look forward to the same relationship as we move forward. I know that we share many goals, such as maintaining a robust aerospace industry, ensuring that our modernization of the air traffic management system is done safely, and sustaining the strength of NASA and our space program going forward. I look forward to working with you during what remains of this session on identifying the common ground that will enable us to develop policies and legislation reflective of this Committee's history of bipartisanship.

A century ago, our nation had the foresight to create the National Advisory Committee for Aeronautics (NACA). NACA, which became NASA, led many breakthroughs in research and design that changed the course of aeronautics and aviation. Today, U.S. civil aviation is a symbol of our nation's ingenuity and ability to design, develop, and manufacture products that are second to none in the world. And as many of my colleagues know, aviation is vital to our economy and to our mobility, as pointed out by the Chairman. In fact, the numbers are staggering. Aviation contributes more than \$1.5 trillion annually to the U.S. economy. It supports 11.8 million direct and indirect jobs, and, it is one of the few U.S. industries that generates a positive trade balance, something we should consider for today, a positive contribution of \$78.3 billion in 2014.

However, it would be unwise for us to just rest on our laurels. Countries with both mature and less mature capabilities are investing in aviation and aeronautics for their strategic contributions to technology, education, workforce development, and global com-

petitiveness. And the market for air travel is changing, with growth in the Asia Pacific region projected to dramatically expand world air traffic by 2050.

With such growth also come challenges. For example, in 2013, U.S. airlines burned 16 billion gallons of jet fuel, and the cost of delays to U.S. airlines during that same year was \$8.1 billion. Increasing fuel efficiency, lessening delays, and minimizing negative environmental effects such as noise and carbon emissions are at the heart of strengthening our civil aviation system.

To that end, experts recognized 15 years ago that the existing approach to managing air transportation was becoming operationally obsolete, and there was a strong concern that the National Airspace System was approaching capacity. Congress established the Next Generation Air Transportation System initiative—known as NextGen—in its 2003 Vision 100 Federal Aviation Administration Reauthorization to address just these concerns. But over the past ten years, FAA’s overall progress in developing NextGen has been slower than expected and the agency is now focused on implementing industry recommendations for near-term benefits.

Mr. Chairman, research and development is providing the tools FAA will need to implement NextGen and improve the nation’s aviation system so that it can respond to changing and expanding transportation needs. Because of the lengthy gestation period needed to move forward from concept to deployment, industry has often been reluctant or unable to apply resources to high-risk, fundamental aeronautics R&D, an investment which is the precursor to bringing new technologies and capabilities to market.

As a result, the federal government, primarily NASA and FAA, in partnership with industry and universities, plays a critical role in carrying out the R&D that enables advances in aviation. So it does concern me, as I am sure it also concerns the Chairman, that Congress has yet to receive FAA’s National Aviation Research Plan for 2015, and even for 2014, despite that fact that those plans are required to be submitted to Congress no later than the time of the President’s annual budget submission. Majority and Minority Members on this Committee need those FAA research plans to inform a reauthorization of FAA’s research and development activities, to carry out oversight, and to assess the contributions that R&D makes to NextGen’s implementation.

For example, we need to know what kind of R&D activities are planned in cybersecurity, software assurance, human factors, and the certification of new technologies into the National Airspace System, all critical areas for the future viability and safety of the National Airspace System.

So I’m looking forward to hearing from our witnesses on the status of aviation R&D activities, because, you see, Mr. Chairman, we need to work together to leverage the expertise and capabilities of government, industry, and our universities. Our reliance on aviation is indisputable, but the challenges are steep if we are to maintain our global preeminence as well as the safety of the nation’s aviation system. I’m confident that properly funded research by NASA and FAA, in collaboration with industry and university partners, will enable us to achieve that goal.

Again, I want to thank our witnesses for appearing before the Subcommittee, and I look forward to your testimony. I thank you, and I yield back.

[The prepared statement of Ms. Edwards follows:]

PREPARED STATEMENT OF SUBCOMMITTEE ON SPACE
RANKING MEMBER DONNA F. EDWARDS

Good morning, and welcome to our panel of witnesses. Mr. Chairman, thank you for calling this hearing to review the current state of U.S. civil aeronautics research and development.

But before I start, allow me to congratulate you on your Chairmanship of this Subcommittee. I know that we share many goals, such as maintaining a robust aerospace industry, ensuring that our modernization of the air traffic management is done safely, and sustaining the strength of NASA and our space program going forward.

I look forward to working with you this session on identifying the common ground that will enable us to develop policies and legislation reflective of this Committee's history of bipartisanship.

A century ago, our nation had the foresight to create the National Advisory Committee for Aeronautics (NACA). NACA, which became NASA, led many breakthroughs in research and design that changed the course of aeronautics and aviation.

Today, U.S. civil aviation is a symbol of our nation's ingenuity and ability to design, develop, and manufacture products that are second to none. And, as many of my colleagues know, aviation is vital to our economy and mobility.

The numbers are staggering:

- Aviation contributes more than 1.5 trillion dollars annually to the U.S. economy.
- It supports 11.8 million direct and indirect jobs.
- And, it is one of the few U.S. industries that generates a positive trade balance—a positive contribution of 78.3 billion dollars in 2014.

However, it would be unwise for us to rest on our laurels.

Countries with both mature and less mature capabilities are investing in aviation and aeronautics for their strategic contributions to technology, education, workforce development, and global competitiveness. And, the market for air travel is changing, with growth in the Asia Pacific region projected to dramatically expand world air traffic by 2050. With such growth come challenges.

For example, in 2013, U.S. airlines burned 16 billion gallons of jet fuel, and the cost of delays to U.S. airlines during that same year was 8.1 billion dollars. Increasing fuel efficiency, lessening delays, and minimizing negative environmental effects such as noise and carbon emissions are at the heart of strengthening our civil aviation system.

To that end, experts recognized fifteen years ago that the existing approach to managing air transportation was becoming operationally obsolete, and there was strong concern that the National Airspace System was approaching capacity.

Congress established the Next Generation Air Transportation System initiative—now known as NextGen—in its 2003 Vision 100 Federal Aviation Administration Reauthorization to address these concerns. Over the past ten years, FAA's overall progress in developing NextGen has been slower than expected and the agency is now focused on implementing industry recommendations for near-term benefits.

Mr. Chairman, research and development—R&D—is providing the tools FAA will need to implement NextGen and improve the nation's aviation system so that it can respond to changing and expanding transportation needs.

Because of the lengthy gestation period needed to move from concept to deployment, industry has often been reluctant or unable to apply resources to high risk, fundamental aeronautics R&D—an investment which is the precursor to bringing new technologies and capabilities to market.

As a result, the federal government, primarily NASA and FAA, in partnership with industry and universities, plays a critical role in carrying out the R&D that enables advances in aviation.

So it concerns me, as I am sure it also concerns the Chairman, that Congress has yet to receive FAA's National Aviation Research Plan for 2015, and even for 2014,

despite that fact that those plans are required to be submitted to Congress no later than the time of the President's annual budget submission.

Majority and Minority Members on this Committee need those FAA research plans to inform a reauthorization of FAA's research and development activities, to carry out oversight, and to assess the contributions that R&D makes to NextGen implementation.

For example, we need to know what kind of R&D activities are planned in cybersecurity, software assurance, human factors, and the certification of new technologies into the national airspace system—all critical areas for the future viability and safety of the National Airspace System.

So I look forward to hearing from our witnesses on the status of aviation R&D activities.

Because, Mr. Chairman, we need to work together to leverage the expertise and capabilities of Government, industry, and our universities. Our reliance on aviation is indisputable, but the challenges are steep if we are to maintain our global preeminence as well as the safety of the nation's aviation system. I am confident that properly funded research by NASA and FAA, in collaboration with industry and university partners, will enable us to achieve that goal.

Again, I want to thank our witnesses for appearing before our Subcommittee, and I look forward to your testimony.

Thank you, and I yield back.

Chairman BABIN. Thank you, Ms. Edwards. I appreciate that, and I too am looking forward to working with you.

I'd like to introduce our witnesses at this time, and the first witness is Dr. Jaiwon Shin. He's the NASA Associate Administrator for the Aeronautics Research Mission Directorate. Dr. Shin also co-chairs the National Science and Technology Council's Aeronautics, Science, and Technology Committee and is also a member of the FAA Research and Development Advisory Committee.

And now I'd like to recognize the gentleman from New Jersey, Mr. LoBiondo, who is the Chair of the Aviation Subcommittee. Thank you for being here.

Mr. LOBIONDO. Yes, Mr. Chairman, thank you, and congratulations. Thank you for the opportunity to sit in on this hearing this morning. Ms. Edwards, thank you very much. Our committees have a lot in common with a lot of common goals and very important issues to discuss, and that's why I'm very pleased this morning to welcome and introduce Dennis Filler, who is the Director of the Federal Aviation Administration's premier facility in the world for traffic management and federal laboratories. There are almost in total a little bit under 5,000 people, incredibly dedicated people who are very inspiring with the work that they do, again for the premier facility in the world for safety and security research and development. Dennis has an expertise with the FAA, joining it in 1992. He is a United States Military Academy graduate from West Point, and incredible skills in both people management but maybe more importantly, understanding that which takes place that sometimes is extremely complicated, and I enjoy hearing the stories of when some of the incredible, smart engineers are discussing their solutions. Dennis actually asked to have the formulas explained to him so he can review their thought process through this. So thank you for allowing Dennis Filler of the FAA's Directorate to be able to testify today.

Chairman BABIN. Thank you, Mr. Chairman. I appreciate you being here this morning.

And Bill Leber is the Co-Chair for the Committee to Review the FAA Research Plan on Certification of New Technologies into the National Airspace System. In addition to serving in this position,

Mr. Leber is also the Vice President for Air Traffic Innovations at PASSUR Aerospace Inc. Thank you for being here.

Mr. John Hansman is the T. Wilson Professor of Aeronautics and Astronautics at the Massachusetts Institute of Technology, or MIT. He is also the Director of MIT's International Center for Air Transportation and the Chair of FAA's Research and Development Advisory Committee. Dr. Hansman is a fellow of the American Institute for Aeronautics and Astronautics.

Dr. Greg Hyslop is the Senior Member at the AIAA and Vice President and General Manager of Boeing Research and Technology and the Chief Engineer for Engineering, Operations, and Technology at the Boeing Company.

And I now recognize Dr. Shin for five minutes. Dr. Shin.

**TESTIMONY OF DR. JAIWON SHIN,
ASSOCIATE ADMINISTRATOR,
AERONAUTICS MISSION DIRECTORATE, NASA;
AND MEMBER FAA RESEARCH AND
DEVELOPMENT ADVISORY COMMITTEE**

Dr. SHIN. Good morning. Chairman Babin, Ranking Member Edwards, Chairman LoBiondo, and Congressman Knight, thanks so much for this opportunity to testify about NASA's aeronautics R&D activities.

NASA's Aeronautics Research Program is making air travel cleaner, safer, and more efficient by developing revolutionary technologies to address a growing demand for mobility, severe challenges to sustainability of energy and the environment, and the advances in information, communication and automation technologies. NASA's research directly benefits the passengers and businesses who rely on aviation every day in the U.S. aviation industry to continue to grow and maintain global competitiveness.

NASA develops game-changing concepts, algorithms and technologies to safely increase throughput and efficiency of the National Airspace System. We work in close partnership with the FAA and the aviation community to enable and extend the benefits of NextGen. Our research programs also focus on major leaps in the safety, efficiency, and environmental performance of subsonic fixed and rotary-wing aircraft to meet growing long-term civil aviation needs and also pioneering low-boom supersonic flight to achieve new levels of global mobility and sustaining hypersonic competency for national needs.

Partnerships are an essential part of NASA aeronautics activities. Our partners include but are not limited to other government agencies, U.S. aviation industry, and universities. One of our most important government partners is the FAA. Over the last several years, NASA, the FAA, and other federal agency members of the Joint Planning and Development Office, or JPDO, by working together defined the vision for the NextGen and established a roadmap to get there over the long term. The FAA's Interagency Planning Office continues to lead the coordination of several key technology focus areas such as the prioritization of UAS-related research and development across federal agencies.

NASA's Air Traffic Management research has been developing advanced ATM tools that will enable more accurate predictions about air traffic, flow, weather, and routing. NASA also has been working to ensure that these tools work well together and demonstrate the potential of widespread use throughout the system.

Our successful model for NASA/FAA collaboration is embodied in Research Transition Teams, or RTTs. RTTs are designed to enhance progress for NextGen advancement in critical areas and effectively transition advanced capabilities to FAA for implementation. RTTs serve as the bridge between NASA's long-term, game-changing technology R&D and the FAA's R&D to support near-term implementation and certification. Under RTTs, NASA and FAA developed joint research plans and fund their respective portions of the plan research according to the nature of the research and their relatively capabilities.

Over the last four years, I am happy to report that NASA has transitioned to five major technologies to FAA. NASA is also researching unmanned aerial systems and, more broadly, inclusive autonomous systems and technologies. NASA's UAS Integration into NAS project is developing technologies that address sense and avoid, communication, and human-machine interaction challenges in order to enable safe and routine UAS access to the NAS.

Through close coordination with FAA's UAS Integration Office, industrial standards organizations and international organizations, NASA's research provides validated findings that inform the FAA's policy and rulemaking processes.

In order to safely enable widespread, small, civilian UAS—which are less than 55 pounds—operations at low altitudes, NASA has initiated research in UAS Traffic Management, or UTM. The goal of UTM is to enable safe and efficient low-altitude airspace operations by providing critical services such as airspace design and geo-fencing, separation management, weather and wind avoidance, routing, and contingency management.

Just as our aeronautics R&D investment over the last 100 years have shaped the aviation system of today, our current portfolio is setting the foundation for the next 100 years of aviation innovation. Business as usual is not going to guarantee the United States' preeminence in the global market nor will it enable us to meet these challenges. We must stay with our proven formula of leadership through technological superiority. NASA aeronautics has a unique and important role in that formula. Long-term, revolutionary aeronautics research has long provided the basis for new concepts and capabilities leading to industry innovation and societal benefits.

ARMD will continue its role of undertaking research and development that falls outside the scale, risk and payback criteria that govern commercial investment.

Thank you again for the opportunity to testify today. I look forward to answering any questions you may have.

[The prepared statement of Dr. Shin follows:]

HOLD FOR RELEASE**UNTIL PRESENTED
BY WITNESS
June 11, 2015****Statement of****Dr. Jaiwon Shin****Associate Administrator for Aeronautics Research
National Aeronautics and Space Administration****before the****Subcommittee on Space
Committee on Science, Space and Technology
U.S. House of Representatives**

Mr. Chairman and Members of the Subcommittee, thank you for this opportunity to testify on NASA's Aeronautics Research program and the research and development challenges in aeronautics.

NASA's Aeronautics research is making air travel cleaner, safer, and more efficient. NASA conducts transformative aeronautics research for long-term leadership, engages in collaborative partnerships to achieve real near- to mid-term results, and infuses high impact research advancements from non-aerospace fields to benefit the aviation community. NASA's aeronautics research continues to play a vital leadership role in air travel and commerce by enabling game-changing technologies and innovation that allow the U.S. aviation industry to continue to grow and maintain global competitiveness. NASA's Aeronautics Research Mission Directorate (ARMD) portfolio is fully aligned with our strategic vision, focusing on the most critical technical challenges to address a growing demand for mobility, severe challenges to sustainability of energy and the environment, and technology advances in information, communications, and automation technologies.

Importance of Aviation

Today's air transportation system is an integral part of the U.S. and global economies. It is the primary mechanism for connecting countries across the world through mobility of populations and mobility of goods and services.

Aviation accounts for more than \$1.5 trillion of total U.S. economic activity annually and is one of the few industries that generates a positive trade balance, \$78.3 billion in 2014 alone. The aviation industry supports more than 11.8 million direct and indirect jobs, including more than one million high-quality manufacturing jobs.

The overarching impacts of aviation and the air transportation system can be felt right down to the individual; just about every product produced and purchased today has been touched by aviation in some way. Air transportation of freight valued at more than \$1.6 trillion occurs every year. U.S. airlines carried more than 761 million passengers in 2014 for both domestic and international flights. Air travelers spend more than \$670.8 billion per year for business and personal travel. In short, the U.S. aviation industry is critical to both the health of the economy and the functioning of our global society.

National Level Challenges

Market factors such as those discussed above point to several key national level challenges facing the aviation industry:

A primary challenge is to ensure that our system continues to meet our demanding expectations of safety, even as new technologies find their way into the system and as air transportation grows around the world. This means changing the way we think about safety so our design methods and certification processes match up with the new technologies entering the system—at the same time as we tackle continuing and emerging safety concerns.

Another important challenge is to improve mobility, both in terms of increasing capacity and saving fuel. This means using less fuel tomorrow to carry passengers and packages than we use to carry them the same distances today, by flying more efficient routes and using more fuel efficient aircraft. It also means increasing the number of flights which can be handled in existing airspace.

A related challenge is to limit the environmental footprint of aviation, which is a top tier concern related to maintaining U.S. industry economic health and avoidance of constraints on operations. Reduced fuel consumption directly reduces greenhouse gas emissions and pollution, but that is not enough. In addition to reducing the amount of fuel used, we must simultaneously reduce the emissions from the fuel that is used and minimize aircraft noise near increasingly busy airports. Translated into numbers, the challenge is to develop technology by 2020 to cut fuel consumption in half, reduce the area of objectionable noise around airports to one sixth of what it is today, and reduce Nitrogen Oxides emissions to half that of the newest aircraft flying today.

The critical challenge—and opportunity—facing manufacturers and airlines is to remain competitive in this growing and increasingly complex market through infusion of new technology. Aviation and aeronautics can enable whole new markets that can spur new avenues of economic growth and job creation. This is not limited to advances in traditional markets—new aircraft and technologies such as Unmanned Aircraft Systems or UAS, may bring radical changes to the way we think about and use aviation.

Research conducted by NASA's Aeronautics Research Mission Directorate has directly benefited today's air transportation system, aviation industry, and the passengers and businesses who rely on aviation every day. The tools and technologies that resulted from this research increased the capacity and improved the efficiency, safety, and environmental compatibility of the air transportation system. Just as our aeronautics research and development investments over the last 100 years have shaped the aviation system of today, our current portfolio is setting the foundation for the next 100 years of aviation innovation.

NASA Strategic Vision

NASA aeronautics guides its efforts with a compelling new strategic vision. This strategy is the culmination of a multi-year effort that included gathering industry and other Government agencies' inputs, systems analysis of environmental and market trends, and the identification of societal mega-drivers. The trend analysis indicated that NASA could best contribute to the Nation's future societal and economic vitality by focusing on efforts that are responsive to a growing demand for mobility, major challenges for energy efficiency and environmental sustainability, and convergence between traditional aeronautical disciplines and rapid technology advances in energy systems, additive manufacturing, and cyber-physical systems. Our investment strategy is outlined in the recently published Strategic Implementation Plan, encompassing our vision for aeronautical research aimed at the next 25 years and beyond.

ARMD's research activities center around six strategic research thrusts:

- Thrust 1: Safe, efficient growth in global operations;
- Thrust 2: Innovation in commercial supersonic aircraft;
- Thrust 3: Ultra-efficient commercial vehicles;
- Thrust 4: Transition to low-carbon propulsion;
- Thrust 5: Real-time, system-wide safety assurance; and,
- Thrust 6: Assured autonomy for aviation transformation.

Each strategic thrust is designed to address an important area of research and technology development that will further U.S. leadership in the aviation industry and enhance safe, sustainable global mobility. NASA's research is performed with an emphasis on multi-disciplinary collaboration focused on the critical, integrated challenges (aligned to the six research thrusts). Together, these research thrusts combine to enable safe, sustainable growth in the overall global aviation system, while pioneering transformative capabilities that will create game-changing opportunities.

To most effectively manage the research needed to address these strategic thrusts, in FY15 NASA has restructured its research programs to achieve three specific goals.

The first goal is to pursue innovative solutions aligned to the strategic thrusts. To do this, NASA has formed three mission programs. They are the Airspace Operations and Safety Program, the Advanced Air Vehicles Program, and the Integrated Aviation Systems Program. Aviation safety research is being directly integrated into the other NASA aeronautics research programs in recognition of the importance of safety considerations in all aspects of our research program. The three mission programs will clearly define the most compelling technical challenges facing the aviation industry, and retire these challenges in a time frame that is supported by the stakeholders and required by NASA's customers.

The second goal is to incentivize multi-disciplinary convergent research. This goal led to the formation of the Transformative Aeronautics Concepts Program. This program will allow for a flexible and organic environment for NASA researchers to develop high-risk, forward-thinking ideas to address aviation's big problems. This environment will allow for rapid demonstration of feasibility and quick turnover of ideas.

The third goal is to enable greater workforce and institutional agility and flexibility. To do this, the Aeronautics Test Program has been integrated into the mission programs. This will embed the flight and ground research into the performing projects to integrate all research phases and to ultimately allow for expanded flight opportunities. It will also enable more agile research practices that combine high-fidelity simulation, ground testing, and flight research.

FY 2015 is a year of transition for NASA Aeronautics to complete this alignment of our Technical Challenges with our strategic research thrusts. Much of the technical content in FY 2014 is continuing in the new program structure with a sharper focus toward achieving timely and compelling impacts to the six strategic thrust areas. We are improving our research management practices to enable the agility and flexibility we desire, while ensuring sound technical management and delivery of results to our stakeholders. Our vision sets us on a course to conduct more effective long term planning, aligning resources and capabilities with a long term vision for transformative changes in aviation.

Aeronautics Research Mission Directorate (ARMD) Programs

Business as usual is not going to guarantee the United States' pre-eminence in the global market, nor will it enable us to meet these challenges. We must stay with our proven formula of leadership through technological superiority. NASA Aeronautics has a unique and important role in that formula. Long-term aeronautics research has long provided the basis for new concepts leading to industry innovation and societal benefits. ARMD will continue its role of undertaking research and development that falls outside the scale, risk, and payback criteria that govern commercial investments.

The *Airspace Operations and Safety Program* develops and explores fundamental concepts, algorithms, and technologies to increase throughput and efficiency of the National Airspace System (NAS) safely. The program works in close partnership with the FAA and the aviation community to enable and extend the benefits of NextGen, the Nation's program for modernizing and transforming the NAS to meet evolving user needs. The program is on the leading edge of research into increasingly autonomous aviation systems, including innovation in the management of UAS traffic and other novel aviation vehicles. The program is also pioneering the real-time integration and analysis of data to support system-wide safety assurance, enabling proactive and prognostic aviation safety assurance.

The *Advanced Air Vehicles Program* develops the tools, technologies, and concepts that enable new generations of civil aircraft that are safer, more energy efficient, and have a smaller environmental footprint. The program focus includes major leaps in the safety, efficiency, and environmental performance of subsonic fixed and rotary wing aircraft to meet growing long-term civil aviation needs; pioneering low-boom supersonic flight to achieve new levels of global mobility; and sustaining hypersonic competency for national needs. The program works in close partnership with academia and industry to pioneer fundamental research and to mature the most promising technologies and concepts for transition to the aviation industry. The program also works on reducing the timeline for development and certification of innovative advanced composite materials and structures. The program sustains and advances key national testing capabilities that support aeronautics research and development.

The *Integrated Aviation Systems Program* focuses on experimental flight research and the spirit of integrated, technological risk taking that can demonstrate transformative innovation. Therefore, the program complements both the Airspace Operations and Safety Program and the Advanced Air Vehicle Program by conducting research on the most promising concepts and technologies at an integrated system level. By the end of FY15, NASA will successfully complete the six-year Environmentally Responsible Aviation (ERA) project with a series of integrated technology demonstrations to demonstrate the feasibility of a suite of technologies to meet our aggressive environmental goals.

The *Transformative Aeronautics Concepts Program* cultivates multi-disciplinary, revolutionary concepts to enable aviation transformation and harnesses convergence in aeronautics and non-aeronautics technologies to create new opportunities in aviation. The program's goal is to demonstrate initial feasibility of internally and externally originated concepts to support the discovery and initial development of new, transformative solutions supporting the Aeronautics strategy. Using sharply

focused activities, the program provides flexibility for innovators to explore technology feasibility and the knowledge base for radical transformation. The program also supports research and development of major advancements in cross-cutting computational tools, methods, and single discipline technologies to advance the research capabilities of all Aeronautics programs.

Partnerships

Partnerships have been an essential part of NASA aeronautics activities since the establishment of its predecessor, the National Advisory Committee for Aeronautics, in 1915 and are based on a clear recognition of the value that's added in sharing knowledge and unique capabilities with others. Our partners include, but certainly are not limited to, other U.S. Government agencies, universities, traditional aeronautics commercial sector representatives and organizations, and foreign government agencies.

Industry partnerships in particular are critical to ensure relevance of our research and in transitioning results to the ultimate end user. Industry also is a valuable cost sharing partner that provides key skills and hardware that NASA doesn't have but is needed for the research to take place. Together our combined efforts are helping to meet the present and future challenges of a globally connected air transportation system.

Partnership in research is critical to our success. Through open competition, we solicit and fund proposals for foundational research by academia, industry, and non-profit organizations via NASA Research Announcements (NRAs) to seek the best new ideas in support of ARMD strategic goals and research objectives. NRAs provide NASA researchers access to fresh ideas, leverage our funds by fostering collaboration between government, industry and academia, and provide universities the opportunity to involve the next generation of engineers in working on today's aeronautics technical challenges. NRA results often serve to identify the "trade space" related to a particular research topic, to identify solutions to particularly difficult problems, or to assist with technology transition.

Through Space Act Agreements, we partner with large and small manufacturers to conduct fundamental research, test novel new concepts and technologies, and leverage their own investments to transition advancements from the laboratory into the field. Through Small Business Innovative Research (SBIR) contracts, we fund innovation by small businesses in foundational aeronautics disciplines in line with our portfolio.

We transfer results of fundamental and systems-level research to the aerospace community through dissemination of research results, concepts, and design methods. In some instances, companies may build on specific technologies and capabilities developed through NASA research, investing their own research and development dollars to take those last steps to become a commercialized product. In other instances, NASA provides design methods and understanding used by companies in developing new products. By maturing new technologies and validating design methods, NASA research can buy down the risk of incorporating new technologies and systems in aircraft, shortening the path through safety certification in the FAA and speeding the transition of new technologies into the fleet.

Implementing NextGen

One of our most important government partners is the Federal Aviation Administration.

Over the last several years, NASA, the FAA and the five other federal agency members of the Joint Planning and Development Office (JPDO) together defined the vision for the Next Generation Air Transportation System (NextGen) and established a roadmap to get there over the long-term. The NextGen JPDO played an important role in helping to establish a common vision for NextGen across government and industry, and coordinate development of the future NAS architecture and concepts of operations. NextGen is being designed to deliver optimal aircraft flight trajectories with better coordinated and managed system-wide operations that will increase capacity and enable aircraft to minimize fuel burn and noise impacts, making it the most efficient aviation system possible.

Since the FAA made a change in interagency coordination from the JPDO to the Interagency Planning Office (IPO), the NextGen IPO has continued to lead the coordination of several key technology focus areas, such as the prioritization of UAS related research and development across federal agencies.

Air traffic controllers currently rely on simple decision support tools to safely separate and maintain an orderly flow of aircraft within the National Airspace System. FAA's traffic forecasts predicted increased traffic, so enhanced tools will maintain and increase system performance. NASA is developing advanced automation tools that will provide controllers with more accurate predictions about air traffic flow, weather, and routing. NASA's Air Traffic Management (ATM) research and development ensures that these tools work well together and demonstrate the potential of widespread use of new procedures throughout the system.

Our successful model for collaboration is embodied in Research Transition Teams (RTTs), which are designed to enhance progress for NextGen advancements in critical areas and effectively transition advanced capabilities to the FAA for certification and implementation. RTTs serve as the bridge between NASA's long term, game-changing technology R&D, and once the capabilities are transferred to FAA, near term R&D to support implementation and certification. Under RTTs, NASA and FAA develop joint research plans and fund their respective portions of the planned research with NASA maturing operational concepts to a certain technology readiness level before transitioning them to the FAA for additional development and eventual implementation.

This model for cross-agency collaboration and cost sharing has been very effective, resulting in several recent demonstrations of advanced technology benefits. Over the last four years, NASA has transitioned to FAA five technologies for certification and integration into mid-term (2014-2018) NextGen operations.

In July 2011, NASA transferred to the FAA tools and methods for in-flight Flow-Based Trajectory Management (FBTM) in the NextGen. The concept of FBTM demonstrated an effective method for successful management of future aircraft traffic densities at levels 30 percent greater than today without additional controller resources. In September 2011, NASA also transferred assessment tools for proposed airspace redesign for FAA's Cleveland Air Route Traffic Control Center (ARTCC).

In November 2011, NASA transitioned the Efficient Descent Advisor (EDA) technology which will save fuel by enabling more efficient arrivals into congested airports. EDA was developed and field tested through a three-year collaborative effort between NASA, FAA, Boeing, MITRE, Sensis/SAAB, United Airlines and Continental Airlines. NASA estimates \$300 million in fuel savings per year during descents if EDA is implemented fleet-wide at the nation's busiest airports. FAA is deploying incremental EDA capabilities as part of its Time Based Flow Management (TBFM) and Enroute Automation Modernization (ERAM) programs with anticipated use by 2018.

NASA transitioned the Precision Departure Release Capability (PDRC) to the FAA in 2013 after a successful field demonstration at the Dallas-Ft. Worth International Airport. PDRC's precision

scheduling of departing aircraft allows for smooth integration into available slots in the high-altitude overhead streams. Missed departure slots in the overhead stream translate to departure delays and lost system capacity. PDRC can result in \$20 million in annual system-wide savings. The FAA is currently conducting investment decision analysis on this capability through the Terminal Flight Data Manager (TFDM) and Time Based Flow Management (TBFM) programs.

NASA is partnering with national airspace system stakeholders to demonstrate the ground-based Controller Managed Spacing combined with the Flight Deck Interval Management technologies to enable fuel and time savings along with increased capacity for early adopters of ADS-B equipment. In order to demonstrate user benefits of these concepts, NASA is jointly working with the FAA to partner with airlines, aircraft manufacturers, avionics manufacturers, ground-based automation system integrators, and airports. NASA transferred the ground-based tool portion of this technology known as Terminal Sequencing and Spacing (TSS) suite to the FAA in July 2014 for near-term deployment through its enhanced terminal productivity program. The automation tool is designed to help air traffic controllers manage airspace within the Terminal Radar Approach Control areas (TRACONS) surrounding major airports, safely permitting more flights to merge together at a point where they can be cleared for a final approach and landing.

TSS just received a final investment decision from the FAA as part of its Time Based Flow Management (TBFM) program, which sets the stage for implementation across the National Airspace System. FAA intends to deploy the software tool throughout the NAS, including five major international airports located in Phoenix, Houston, Atlanta, Seattle and Los Angeles, before 2018.

NASA continues its development of algorithms for managing airplane traffic on the ground that will lead to reduced surface congestion enabled by NASA's Spot and Runway Departure Advisor (SARDA) technology. Benefit studies for several complex U.S. airports show a taxi delay reduction of between three to five minutes resulting in annualized fuel savings of \$2.5 million to \$7.5 million at each airport using these algorithms. A series of simulations leading up to field demonstrations at a major commercial airport are being planned to facilitate the transition of this technology to the FAA in the coming two years.

NASA R&D is helping to enhance NextGen through transfer of technology to industry as well. Some airspace operations tools can be applied directly by airlines in the existing air traffic control system yielding near term benefits.

For example, NASA has developed a tool that combines National Weather Service real-time data with Air Traffic Control departure scheduling to provide enhanced decision support capability to FAA's Ground Delay Program. FAA, along with NASA's support, conducted trials of this new capability at San Francisco International Airport (SFO) and demonstrated a significant reduction in ground delays due to morning fog compared with the current ground delay policy at SFO, which often leads to excessive and unrecoverable delays affecting the entire country. Seventy percent of air traffic delays are caused by bad weather. Until now, airline dispatchers and FAA traffic managers didn't have a way to continuously reevaluate the weather avoidance routes for each flight, which are typically put in place before the aircraft departs. NASA's Dynamic Weather Rerouting (DWR) tool will enable dynamic, "real-time" adjustments to flight paths to avoid bad weather with minimum delay while also saving fuel. The tool integrates trajectory-based automation designed for Center radar controllers, convective weather modeling that predicts the growth and movement of storms, and algorithms to automatically compute minimum-delay routes around bad weather. DWR has the potential to provide significant savings to airlines against those overall operational costs in flight and on the ground. American Airlines participated in DWR technology

demonstrations and has incorporated this tool into daily operations. NASA is working with other industry partners to make this tool more broadly available.

Looking to the near future, we are partnering with the FAA, manufacturers, airlines and airports to conduct near-term demonstrations, planned for 2017, of fuel-saving air traffic management concepts enabled by the satellite navigation capability of NextGen through the ATM Technology Demonstrator-1 or ATD-1 activity. Through simulations and flight trials of a complex, integrated set of ground-based and flight deck technologies, we will demonstrate to airlines the return on investment they can achieve by equipping their aircraft with NextGen avionics such as Automatic Dependent Surveillance – Broadcast (ADS-B) equipment.

Looking further ahead, we plan to demonstrate a full suite of Integrated Arrival/Departure/Surface (IADS) tools which will enable further revolutionary advances in air transportation. This will be done jointly with the FAA in response to the NextGen Advisory Committee recommendations for near term technology demonstrations.

UAS / Autonomy – Multilevel Coordination

NASA also is researching other technologies which hold great promise for the transformation of our future aviation system, including Unmanned Aircraft Systems and more broadly inclusive autonomous systems and technologies. All elements of an aviation system could possess some level of autonomy, ranging from flight vehicles to air traffic management, ground support vehicles, ground control stations and all other elements. The introduction of autonomous vehicles and technologies can usher in totally different flight vehicles and operations that are unimaginable today and open up entirely new commercial markets, benefitting consumers as well as manufacturers, much as jet engines did 60 years ago.

The majority of NASA’s research work toward near-term integration of UAS into the National Airspace System is focused on contributing capabilities that reduce technical barriers related to the safety and operational challenges associated with enabling routine UAS access to the NAS. Through close coordination with the FAA’s UAS Integration Office, industry standards organizations, and international organizations, NASA’s research provides validated findings that inform the FAA’s policy and rule-making processes.

NASA also is researching novel concepts and technologies that may facilitate safe operation of UAS at altitudes that are not actively controlled today, such as low-altitude operation of small UAS (less than 55 pounds). Initial investigations in this capability have drawn interest among a broad range of traditional and non-traditional aerospace companies and show promise of opening up entirely new markets and operational models. In order to safely enable widespread civilian UAS operations at lower altitudes, NASA is initiating development of an air traffic management-like system called UAS Traffic Management (UTM). The goal of UTM is to enable safe and efficient low-altitude airspace operations by providing critical services such as airspace design and geo-fencing, separation management, weather and wind avoidance, routing, and contingency management.

The growing UAS industry and the varied user base is a harbinger for change that increasingly autonomous systems will bring to aviation. It has the potential to revolutionize existing transportation applications and enable fundamentally new uses of the NAS. But enabling these changes will require substantial research and experimentation to ensure the safety and efficacy of these systems. As the National Research Council (NRC) Committee on Autonomy Research for Civil Aviation indicated in their recent report on the subject – “civil aviation is on the threshold of potentially revolutionary changes

in aviation capabilities and operations associated with increasingly autonomous systems. These systems, however, pose serious unanswered questions about how to safely integrate these revolutionary technological advances into a well-established, safe, and efficiently functioning NAS."

NASA's long-term research in autonomy seeks to answer both those questions as well as to demonstrate high payoff, integrated applications that advance the safety, efficiency and flexibility of the NAS and increase competitiveness of the U.S. civil aviation industry. Through internal assessments and taking advantage of the previously mentioned NRC Committee's report, NASA has developed a set of research themes that are critical to enabling assured autonomy. These research themes include: advancing test, evaluation, verification and validation techniques; developing autonomous planning, scheduling and decision-making methods; developing the tools to design and analyze autonomous systems; and systems for integrated vehicle control, health management and adaptation.

Future Work

Over the next two years, NASA will continue to develop, demonstrate and transition new vehicle and airspace management concepts and technologies to industry and the FAA as well, to provide technical data, analysis and recommendations to support the integration of UAS into the NAS. We will strengthen our external partnerships through joint flight demonstrations of advanced flight deck and vehicle technologies, and through demonstrations of advanced sensors to improve safety and identify emerging faults before damage occurs.

We are developing roadmaps in key areas such as autonomy and low carbon propulsion, informed through community engagement and studies commissioned through the National Research Council.

Also we are looking beyond traditional aeronautics for technology partners that could transform aviation. We're looking to how technologies that are revolutionizing other industries might do the same if applied to aviation – like smart materials such as shape memory alloys and self healing materials, additive manufacturing (3D printing), and information technology. NASA already works in some of these areas but the leaps-and-bounds advances in other parts of the economy could move us along even faster.

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Conclusion

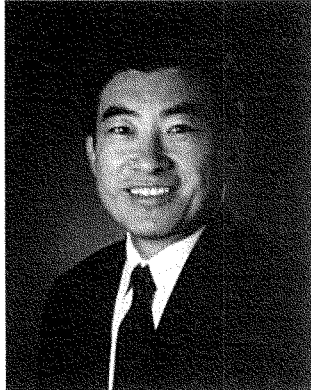
In summary, NASA does not build aircraft, engines, or air traffic management systems. Through the research we conduct and research we sponsor with universities and industry, we help to develop the technology that enables continuous innovation in aviation. U.S. companies are well positioned to build on discoveries and knowledge resulting from NASA research, turning them into commercial products, benefiting the quality of life for our citizens, providing new high-quality engineering and manufacturing job opportunities, and enabling the U.S. to remain competitive in the global economy.

NASA Aeronautics has experienced tremendous success through the past years by committing to the core principles of:

- valuing innovation and technical excellence;
- aligning our research to ensure a strong relevance to national needs;
- transferring technology in a timely and robust manner;
- maintaining strong partnerships with other government agencies, industry and academia; and
- inspiring the next generation of engineers and researchers.

Our planned research for the upcoming years will continue to provide valuable benefits to the aviation community and the Nation.

NASA - Associate Administrator for Aeronautics Research Mission Directorate Jaiwon Shin



Dr. Jaiwon Shin
Credits: NASA

Dr. Jaiwon Shin is the NASA Associate Administrator for the Aeronautics Research Mission Directorate. In this position, he manages the agency's aeronautics research portfolio and guides its strategic direction. This portfolio includes research in the fundamental aeronautics of flight, aviation safety and the nation's airspace system.

Shin co-chairs the National Science & Technology Council's Aeronautics Science & Technology Subcommittee. Comprised of federal departments and agencies that fund aeronautics-related research, the subcommittee wrote the nation's first presidential policy for aeronautics research and development (R&D). The policy was established by Executive Order 13419 in December 2006 and will guide U.S. aeronautics R&D programs through 2020. The subcommittee finished writing the National Aeronautics R&D Plan in December 2007 and is currently writing the Research, Development, Test and Evaluation (RDT&E) Infrastructure Plan both of which were called for by the Executive Order.

Between May 2004 and January 2008, Shin served as deputy associate administrator for the Aeronautics Research Mission Directorate where he was instrumental in restructuring NASA's aeronautics program to focus on fundamental research and better

align with the nation's Next Generation Air Transportation System (NextGen).

Prior to coming to work at NASA Headquarters, Shin served as chief of the Aeronautics Projects Office at NASA's Glenn Research Center. In this position he had management responsibility for all of the center's aeronautics projects. Prior to this he was Glenn's deputy director of aeronautics, where he provided executive leadership for the planning and implementation of Glenn's aeronautics program, and interfaced with NASA Headquarters, other NASA centers, and external customers to explore and develop technologies in aeropropulsion, aviation safety and security, and airspace systems.

Between 1998 and 2002, Shin served as chief of the Aviation Safety Program Office, as well as the deputy program manager for NASA's Aviation Safety Program and Airspace Systems Program. He assisted both program directors in planning and research management.

Dr. Shin received his doctorate in mechanical engineering from the Virginia Polytechnic Institute and State University, Blacksburg, Virginia. His bachelor's degree is from Yonsei University in Korea and his master's degree is in mechanical engineering from the California State University, Long Beach. His honors include NASA's Outstanding Leadership Medal, NASA's Exceptional Service Medal, a NASA Group Achievement Award, Lewis Superior Accomplishment Award, three Lewis Group Achievement Awards, and an Air Force Team Award. He is a graduate of the Senior Executive Fellowship Program at the Kennedy School of Government at Harvard University. He has extensive experience in high speed research and icing, and has authored or co-authored more than 20 technical and journal papers.

Chairman BABIN. Thank you, Dr. Shin.
I'd like to recognize Mr. Filler now for five minutes. Mr. Filler.

**TESTIMONY OF MR. DENNIS FILLER, DIRECTOR,
WILLIAM J. HUGHES TECHNICAL CENTER, FAA**

Mr. FILLER. Good morning. Chairman Babin, Ranking Member Edwards, and Members of the Subcommittee, thank you for this opportunity to appear before you today to discuss the Federal Aviation Administration's aviation research and development portfolio. I am Dennis Filler. I'm the Director of the William J. Hughes Technical Center. I also serve as the FAA's Director of Research. In that capacity, I am responsible for managing the FAA's aviation research program.

Aviation is a vital resource for the United States. To maximize the opportunities that the aviation industry provides, the FAA must not only maintain, but continually improve, the National Airspace System, or NAS. Collaborative, needs-driven research, engineering and development is central to this process. The FAA's research portfolio enables the United States to remain a world leader in providing safe, efficient, and environmentally sound air transportation.

FAA research, and specifically research conducted at our Technical Center in Atlantic City, has contributed to making aviation safer, both at home and abroad. For more than 50 years, the FAA's world-renowned researchers, scientists, and engineers have developed technologies, standards, and procedures that prevent inflight fires and improve survivability. The National Transportation Safety Board recognizes the Technical Center's contributions in fire safety research saved lives during the horrific Asiana Airlines crash in 2013.

In addition to making aviation safer, FAA research is making it more efficient. Key NextGen foundational programs such as ADS-B, ERM, and DataComm have all been developed, tested or began their nationwide deployment at the Technical Center through our unique engineering, test, evaluation and sustainment activities. Collectively, these programs will deliver operational efficiencies into the National Airspace System.

Our applied research is also delivering near-term benefits. For example, our research into minimum wake turbulence separation standards has allowed us to safely recategorize distances needed between aircraft, which increases efficiency and reduces flight delays. Because of wake RECAT, FedEx can take advantage of a 13 percent increase in departure capacity at Memphis, and at Atlanta's Hartsfield-Jackson Airport, Delta Airlines projects reduced delays will save \$14 to \$19 million in operating costs over a one-year period.

Greater efficiency also reduces the environmental impact of aviation. The FAA is invested in accelerating new technologies that reduce fuel burn, noise and emissions through the Continuous Lower Energy Emissions and Noise program, or CLEEN. This public-private partnership leverages limited federal funds to develop technology to make today's aircraft fleet quieter and more fuel-efficient.

Aviation is constantly evolving and there will always be a need for applied research in response to these changing needs. That is

why we are conducting robust research around new entrants to the airspace such as unmanned aircraft systems, or UAS.

Recently, we announced the selection of a new Center of Excellence for UAS, which will be led by a team from Mississippi State University. The Center of Excellence will focus on research, education and training in areas critical to the safe integration of UAS into the nation's airspace. Also, as part of the Pathfinder program, we're leveraging industry interests in UAS applications to further explore other integration opportunities. The trials performed in this program could yield valuable data to further FAA-approved UAS operations.

While we respect our past and its legacy, our vision is firmly fixed on the future. We're committed to ensuring that the United States continues to lead the world in the development and implementation of aviation technology while we continue to operate the safest and most efficient aviation system in the world.

This concludes my statement. I'll be happy to answer any of your questions.

[The prepared statement of Mr. Filler follows:]

**STATEMENT OF DENNIS L. FILLER, DIRECTOR, WILLIAM J. HUGHES
TECHNICAL CENTER, FEDERAL AVIATION ADMINISTRATION, BEFORE THE
HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY,
SUBCOMMITTEE ON SPACE: TRANSFORMING AMERICA'S AIR TRAVEL,
JUNE 11, 2015.**

Chairman Babin, Ranking Member Edwards, and Members of the Subcommittee:

Thank you for the opportunity to appear before you today to discuss the Federal Aviation Administration's aviation research and development portfolio. I am Dennis Filler, Director of the William J. Hughes Technical Center. I also serve as the FAA's Director of Research. In that capacity, I am responsible for managing the FAA's aviation research program.

Aviation is a vital resource for the United States. It provides opportunities for business, job creation, economic development, law enforcement, emergency response, personal travel, and leisure. It attracts investment to local communities and opens up new domestic and international markets and supply chains. To maximize the opportunities that the aviation industry provides, the U.S. must not only maintain, but also continue to improve upon, the National Airspace System (NAS).

The FAA works to ensure that the NAS remains responsive to rapidly changing and expanding transportation needs while ensuring the highest level of safety. Collaborative, needs-driven research and development (R&D) is central to this process, because it enables the United States to be a world leader in its ability to move people and goods by air safely, securely, quickly, affordably, efficiently, and in an environmentally sound manner. Today, I would like to provide

you with an overview of our R&D assets, activities, and significant accomplishments in support of our ongoing commitment to modernize the U.S. air transportation system.

The FAA William J. Hughes Technical Center

Since 1958, the FAA William J. Hughes Technical Center has served as the core facility for modernizing the air traffic management system, and for advancing programs to enhance aviation safety, efficiency, environmental responsibility and capacity. The Technical Center is the nation's premier air transportation system laboratory. The Center's highly technical and diverse workforce conducts research and development, test and evaluation, verification and validation, sustainment, and ultimately, de-commissioning of the FAA's full spectrum of aviation systems. They develop scientific solutions to current and future air transportation safety, efficiency, environmental and capacity challenges. Technical Center engineers, scientists, mathematicians, and technical experts utilize a robust, one-of-a-kind, world-class laboratory environment to identify integrated system solutions for the modernization and sustainment of the NAS and for integrating new operational capabilities and technologies.

Successful Technical Center efforts are reflected in aviation advances across the country and indeed, around the world. The Center has assumed a leadership role in promoting international interoperability and global harmonization, through standards and technical guidance to other countries. The Technical Center has contributed to aviation safety in countless ways. Some unique Technical Center laboratories include: air traffic management and simulation facilities, a human factors laboratory, the NextGen Integration and Evaluation Capability, a Cockpit Simulation Facility, a fleet of specially-instrumented in-flight test aircraft, the world's largest full-scale aviation fire test facility, a chemistry laboratory for analyzing the toxicity of materials

involved in a fire, surveillance test laboratories, a full-scale aircraft structural test evaluation and research facility, the National Airport Pavement Test Facility, and a UAS research and development simulation laboratory. The Technical Center also provides strategic direction to the agency's Research, Engineering, and Development (RE&D) portfolio and ensures that it is integrated, well planned, budgeted and executed.

Civil Aerospace Medical Institute

The FAA Civil Aerospace Medical Institute (CAMI), located at the Mike Monroney Aeronautical Center in Oklahoma City, Oklahoma, focuses on the human element in flight—pilots, flight attendants, passengers, air traffic controllers—and the entire human support system that embraces civil aviation. Using laboratory research and advanced simulators, CAMI studies the factors that influence human performance in the aerospace environment and looks for ways to improve performance, efficiency, and overall safety. CAMI also conducts important research to evaluate adverse events that occur in aerospace operations and discover methods to enhance human safety, security, health, and performance.

Leveraging Partnerships

1. Centers of Excellence

In conjunction with the ongoing work at the Technical Center, the FAA has an extensive program to foster research and innovative aviation solutions through the nation's colleges and universities. By doing so, it leverages the nation's significant investment in basic and applied research and helps to build the next generation of aerospace engineers, managers, and operators. The Centers of Excellence (COE) program encourages collaboration between government, academia, and industry to advance aviation technologies and expand FAA research capabilities

through required matching contributions. In 2014, the FAA sponsored six active public-private research centers throughout the U.S. with academic institutions and their industry and other affiliates. These are:

- COE for Alternative Jet Fuels and Environment
- COE for General Aviation Safety, Accessibility and Sustainability
- COE for Commercial Space Transportation
- COE for Research in the Intermodal Transport Environment
- Joint COE for Advanced Materials
- COE for Partnership for Air Transportation Noise and Emission Reduction

Recently, after a rigorous competition, the FAA announced the selection of a team from Mississippi State University as the FAA's Center of Excellence for Unmanned Aircraft Systems (UAS). The COE will focus on research, education and training in areas critical to safe and successful integration of UAS into the nation's airspace. The team brings together 15 of the nation's leading UAS and aviation universities that have a proven commitment to UAS research and development and the necessary resources to provide the matching contribution to the government's investment. We expect that the COE will be able to begin research by September 2015 and be fully operational and engaged in a robust research agenda by January 2016.

2. Industry

The FAA has partnered with three leading U.S. companies—CNN, PrecisionHawk, and BNSF Railroad—in a new project to research the next steps in UAS operations beyond those proposed in the small UAS Notice of Proposed Rulemaking, published in February 2015. This project, known as the Pathfinder Program, will focus on three areas: (1) visual line-of-sight operations for newsgathering in urban areas (CNN); (2) extended visual line-of-sight operations for

surveying crops in rural areas (PrecisionHawk); and (3) beyond visual-line-of sight operations to inspect rail infrastructure in rural/isolated areas (BNSF). The FAA has already been working with CNN through a Cooperative Research and Development agreement and is working on similar partnerships with PrecisionHawk and BNSF. We anticipate that these research trials will yield valuable data that eventually may result in FAA-approved UAS operations.

3. Government

The FAA's partnership with NASA is a valuable part of NextGen development and implementation. NASA, in cooperation with the FAA, develops and matures their technology to a level where it can be transferred to the FAA for further testing and evaluation. The FAA, in turn, generates functional specifications to make the technology portable, sustainable, and deployable in the NAS. These functional specifications are integrated into product system builds and delivery schedules to ensure that training, testing, and full NAS wide systems level performance can be maintained.

NASA/FAA Research Transition Teams have moved several NextGen capabilities from research to reality. For example, we are preparing to deploy a new tool developed by NASA—Terminal Sequencing and Spacing—that will assist air traffic controllers in managing terminal airspace. This technology will allow pilots to fly fuel-efficient, continuous-descent approaches toward an airport, reducing emissions and resulting in greater efficiency and cost savings. FAA is also collaborating with NASA on a 5-year research activity, Airspace Technology Demonstration 2 (ATD-2), which will focus on the scheduling of departures within a metroplex terminal environment to create similar efficiencies for departing aircraft.

Recent Accomplishments

The FAA's research and development (R&D) mission is to conduct, coordinate, and support both domestic and international research and development of aviation-related products and services that will ensure a safe, efficient, and environmentally sound global air transportation system.

Three core principles guide the FAA's R&D activities: (1) Improve Aviation Safety; (2) Improve Efficiency; and (3) Reduce Environmental Impacts. Through our work at the Technical Center and collaboration with our partners in industry, government, and academia, we have made significant accomplishments in each of these core areas.

1. Improve Aviation Safety -- Fire Safety

Aircraft fire safety prevention has always been an FAA priority. For more than 50 years, the FAA has worked with the researchers and engineers at the Technical Center to develop technologies and design procedures to prevent in-flight fires and improve survivability. The Technical Center is widely recognized as a leader in fire protection research and has a unique Full-Scale Fire Test Facility that allows for the conduct of realistic aircraft fire tests under controlled conditions.

FAA has been actively engaged in research and testing to develop technologies and procedures to improve the safe transportation of lithium batteries. Numerous tests conducted at the Technical Center's Fire Test Facility, including a very-realistic full-scale test in the cargo compartment of a Boeing 727, show that lithium metal (non-rechargeable) batteries pose a different risk than lithium-ion batteries, which are the more common re-chargeable type. The 727 tests and separate testing of cargo compartment fire resistant containers and fire containment covers revealed that current fire suppression technologies are ineffective against lithium metal

battery fires. The fire resistant container testing also revealed that lithium-ion batteries in thermal runaway generate significant smoke and vent flammable gases that create an explosion hazard.

The Technical Center's research directly supports and advances the position of the U.S. delegation on the ICAO Dangerous Goods Panel, which develops international standards for the safe transportation of all hazardous materials. As a result of this work, the FAA was able to bring necessary attention to the safety risks presented by bulk shipments of lithium batteries to achieve a global ban on their transportation as cargo aboard passenger aircraft. The FAA is continuing to conduct research and testing to address and mitigate the safety risks associated with bulk shipments of lithium batteries on all-cargo aircraft.

2. Improve Aviation Safety – UAS Research and Development

The FAA is committed to the safe integration of UAS into the nation's airspace. Our UAS R&D Portfolio includes the UAS Center of Excellence, interagency UAS partnerships, UAS modelling and simulations at the Technical Center, UAS flight demonstrations, and all of the aviation safety research defined by the FAA's UAS Integration Office and funded by the FAA's UAS RE&D budget line item.

The FAA works in close partnership with NASA on UAS R&D in order to leverage the expertise, capabilities and research results of the two agencies. Since the inception of NASA's UAS in the NAS research program, FAA has been a key partner collaborating on UAS simulations and flight tests as well as providing operational expertise and support from our air traffic controllers. In October 2014, FAA and NASA established another in a series of Research Transition Teams to explore NASA's UAS Traffic Management (UTM) concept for enabling

safe UAS operations in low-altitude airspace to address evolving UAS civilian applications, from goods delivery and infrastructure surveillance, to search and rescue, and agricultural monitoring. NASA's near-term goal is the development and demonstration of the UTM to safely enable low-altitude airspace and UAS operations within five years. For the longer-term (10 to 15 years in the future), the goal is to safely enable the anticipated dramatic increase in density of all low-altitude airspace operations.

3. Improve Efficiency – NextGen Wake RECAT

The Technical Center is the primary aviation facility responsible for conducting research, engineering, development, testing, and NAS integration activities required to support NextGen. ADS-B, ERAM and DataComm were all developed, tested and began their nation-wide deployment at the Technical Center through its engineering, testing, evaluation, and deployment platforms.

The FAA has prioritized the use of Multiple Runway Operations as part of its commitment to modernize the NAS. Through research with our government and industry partners, we have engaged in a process to re-categorize required minimum wake turbulence separation standards based on the performance characteristics of aircraft (wake RECAT). This re-categorization updates and decreases separation standards, which increases efficiency and reduces flight delays. The FAA had been using five wake turbulence separation categories formulated 20 years ago, based primarily on aircraft weight. Now, based on a closer analysis of much more nuanced data there are six.

Phase I of wake RECAT was first implemented at Memphis International Airport in 2012. The adjustment to the wake separation standards increased the throughput rate (number of departures

and arrivals) and improved airport efficiency. In 2014, FAA continued the implementation of Phase I at Cincinnati/Northern Kentucky Airport and Hartsfield-Jackson Atlanta International Airport. To date, wake RECAT has provided real benefits to air carriers. FedEx can take advantage of a 13 percent increase in departure capacity at Memphis. At Atlanta's Hartsfield-Jackson airport, Delta Airlines and FAA have found a one and one-half minute reduction in departure queue delays and Delta projects to save \$14-19 million dollars in operating costs over a one-year period.

The work on wake RECAT continues today. A separation matrix for Phase II of the project has been developed for 107 aircraft types, which covers approximately 99 percent of the aircraft flown in the NAS. Additionally, an optimization tool was developed to allow each TRACON to create wake separation aircraft categories from the matrix that will provide the greatest increase in runway throughput for the airports it services. Implementation of Phase II will begin following the approval of safety documentation and updates to the FAA order that defines separation standards in the NAS.

4. Reduce Environmental Impacts – Aircraft Technology

The FAA's environmental vision is to provide environmental protection that allows sustained aviation growth. Although there are a range of environmental issues associated with aviation, noise, air quality, climate, energy, and water quality are considered to be the environmental aspects with the greatest potential to constrain aviation capacity, efficiency and flexibility.

Aircraft technology advances have been the primary factor in reducing aviation's environmental footprint and will continue to be key in the future. Realizing the potential of technology, the FAA is invested in accelerating development and commercialization of new technologies that

reduce fuel burn, noise and emissions through the Continuous Lower Energy, Emissions, and Noise Program, or “CLEEN.”

CLEEN is a public-private partnership in which the FAA leverages Federal investment by partnering with industry. The FAA has awarded contracts worth \$125 million to 5 companies and these companies agreed to contribute at least equal amounts -- for a total of more than \$250 million. CLEEN is designed to promote and invigorate efforts to develop technology that can be incorporated into today’s aircraft fleet and begin making a difference in the near-term. Based on the successes of the first phase of CLEEN, we are moving forward with a second phase of CLEEN that will run from 2015 through 2020.

5. Reduce Environmental Impacts -- Airport Asphalt

The FAA has operated a state-of-the-art, full-scale pavement test facility dedicated solely to airport pavement research since 1999, teaming with Boeing on the construction and operation of the building, test track, and test vehicle (National Airport Pavement Test Facility - NAPTF). This year, the Technical Center completed construction and took possession of the new National Airport Pavement and Materials Research Center (NAPMRC), which has expanded research capabilities, including a custom-designed heavy-vehicle simulator (airfield version) or HVS-A.

A key objective of the test facility and the HVS-A is to research environmentally friendly technologies like warm-mix, stone-matrix, recycled asphalt shingles, and recycled asphalt pavements. Current FAA advisory circulars lack guidance on such asphalt pavements because of the limited knowledge about how high tire pressure and heavy gear loads affect airport pavement performance. This is the primary reason for the limited use of “green”, or more environmentally friendly, pavement materials. Research at the test facility is aimed at increasing the use of

greener materials, more durable airport pavements and locally available materials modified with admixtures that enhance pavement durability, workability, and strength. This will help save money by lowering the costs of initial construction, maintenance and repairs.

The original pavement test facility features a rail-based test vehicle inside a fully enclosed building. It does a great job examining the impact of wheel loads on lower layers of pavement. But it cannot heat the pavement effectively because it moves over rails. By contrast, the HVS-A is mobile, can be operated with a remote control, and includes an automated heating system with 12 heating panels inside the structure. The machine gives engineers the ability to replicate and analyze the damage that heavy commercial jets can do to the top asphalt layer of pavement when it gets hot, particularly during the slow-moving trek between the gate and runway. The older rail-based test vehicle also uses full landing gear configurations to gauge the impact of wheel-load interactions at lower depths, but within the HVS-A, one wheel is sufficient for testing due to insignificant wheel load interactions in the pavement surface layers.

The HVS-A gives the Technical Center the ability to test asphalt materials at very high tire pressures and temperatures. This is important because even at airports as far north as John F. Kennedy International Airport in New York, pavement temperatures can reach 140-150 degrees Fahrenheit. The new generation aircraft, such as the Boeing 787 and Airbus 350, have tire pressures in the range of 220 to 250 pounds per square inch. The remote control will be used to move the HVS-A between the existing outdoor pavement test strips and two more strips inside a new fabric building, which will allow for testing in a more controlled environment and for continuous research. The test facility and HVS-A also make it possible to test materials and

ideas other than pavement, such as marking paint technologies and rumble strips for preventing runway incursions.

Conclusion

The aviation industry is marked by constant evolution and there will always be a need for research and evolving technology in response to changes in aviation needs. While we respect our past and its legacy, our vision is firmly fixed on the future and how we can best be prepared to meet its challenges and maximize our nation's ability to respond to aviation-based opportunities while performing at our present global standard of excellence. We are committed to ensuring that the United States continues to lead the world in the development and implementation of aviation technology and to operate the safest and most efficient aviation system in the world.

This concludes my statement. I will be happy to answer your questions at this time.

Dennis L. Filler
Director, FAA William J. Hughes Technical Center

Dennis L. Filler is the Director of the Federal Aviation Administration's (FAA) William J. Hughes Technical Center (WJHTC) in Egg Harbor Township, N.J. The FAA William J. Hughes Technical Center serves as the nation's premier aviation and air traffic management federal laboratory. The Technical Center's world-class laboratories and top-notch engineering expertise place it at the forefront of the FAA's efforts to modernize the U.S. air transportation system and advance the Next Generation Air Transportation System, NextGen. The WJHTC is the primary agency aviation facility responsible for conducting research, engineering, development, test, and National Airspace System (NAS) integration activities required to support and advance the nation's NextGen systems and our legacy airspace. Mr. Filler also serves as the FAA Director of Research and manages the \$160 million budget of the aviation research program.

Mr. Filler joined the FAA in 1992 after holding a variety of engineering and management positions in both industry and government settings. He has worked in small business environments managing engineering product development and services delivery. He has successfully managed his own small business consulting firm, providing support to all business sizes and the federal government. He also worked for Lockheed Martin before joining the FAA.

Within the FAA, he has served in many roles both at the WJHTC and FAA headquarters. He has worked as an engineer, Human Factors Laboratory Manager, NAS Systems Engineering and Concepts Analysis Division manager, Chief Scientist for Technology, Acting Deputy Center Director, and Chief Information Officer for the Air Traffic Organization.

As a graduate of the United States Military Academy at West Point, he served as a U.S. Army Signal Corps commissioned officer specializing in communications and electronic warfare systems design and implementation.

As Center Director, he strives to identify barriers to change and fosters the creation of environments where people with the right knowledge, skills and abilities are strategically combined with best practice processes and state of the art technology to deliver data-supported solutions across all elements and domains of our NAS.

Chairman BABIN. Thank you, Mr. Filler. Thank you very much. Now I recognize Mr. Leber for five minutes.

**TESTIMONY OF MR. WILLIAM LEBER,
CHAIR, NATIONAL RESEARCH COUNCIL REPORT TITLED
“TRANSFORMATION IN THE AIR—A REVIEW
OF THE FAA RESEARCH PLAN;”
AND VICE PRESIDENT,
AIR TRAFFIC INNOVATIONS, PASSUR AEROSPACE**

Mr. LEBER. Thank you, and good morning, Mr. Chairman, Ranking Member, Members of the Committee. Thank you for the opportunity to speak to you today on issues concerning civil aeronautics research and the FAA reauthorization.

I'm here today in my capacity as one of the Co-Chairs of the Committee of the National Research Council, which recently reviewed an FAA research plan for certification of new technologies. That report was requested in the FAA Modernization and Reform Act of 2012. It was released on Monday, June 8, 2015.

Mr. Chairman, before commenting on the findings of our report, I want to make clear that our committee had a very narrow and limited charge. We were asked to review and comment on this one research plan. The FAA has many other plans for research and for other aspects of the implementation of NextGen. We were not asked to and did not review those other plans.

Our committee found that the February 2014 certification research plan does not demonstrate how integration of aircraft, ground systems, and procedures will occur in the National Airspace System. It in particular omitted any substantive discussion of the air segment. Successfully demonstrating how integration will occur will create confidence in the implementation and, we believe, attract stakeholder and operator investment.

Mr. Chairman, our committee believes that all stakeholders will benefit substantially from the explanation of the end-to-end processes necessary to certify, approve, and implement advanced NextGen capabilities beyond the mid-term, that is, five to seven years. In our view, a new FAA plan should outline how the agency can best coordinate its research with other relevant organizations, particularly NASA, which conducts significant research of relevance on air traffic systems.

I thank you for the opportunity to speak to you about this important National Research Council report, and I look forward to addressing your questions.

[The prepared statement of Mr. Leber follows:]

Testimony of
William Leber
Chair, Committee to Review the Federal Aviation
Administration Research Plan
on Certification of New Technologies into the National
Airspace System

Aeronautics and Space Engineering Board
Division Committee on Engineering and Physical
Sciences
National Research Council
The National Academies
before the
Subcommittee on Space,
Committee on Science, Space, and Technology,
U.S. House of Representatives
June 11, 2015

Mister Chairman, ranking member, members of the committee, thank you for the opportunity to speak to you today on issues concerning civil aeronautics research and the FAA reauthorization. I am here today in my capacity as one of the co-chairs of the committee of the National Research Council which recently reviewed a FAA research plan for certification of new technologies. That report was requested in the FAA Modernization and Reform Act of 2012 and was released on Monday, June 8, 2015.¹

In response to the 2012 Act, the FAA Office of NextGen prepared a 10-page certification research plan² for the Next Generation Air Transportation System (NextGen). The report was completed in February 2014 and approved by FAA management for release to the NRC in April 2014. In response to the request to review the research plan, the National Research Council created a committee that gathered data from the FAA, Congress, industry, and other sources to assist in its review. The committee received briefings from the author of the Research Plan and was able to have a dialogue with relevant FAA officials to understand the management guidance that went into generating it.

Mr. Chairman, before commenting on the findings of our report I want to make clear that our committee had a very limited charge. We were asked to review and comment on this one research plan. The FAA has many other plans for research and for other aspects of the implementation of NextGen, we were not asked to and did not review those other plans. In addition you

¹ National Research Council, *Transformation in the Air—A Review of the FAA's Certification Research Plan*, Prepublication Draft, June 2015.

² FAA, *Research Plan: Methods and Procedures to Improve Confidence in and Timeliness of Certification of New Technologies Into the National Airspace System: Final*, Office of NextGen, Washington, D.C., February, 2014.

may be aware that the National Research Council also recently released a report “A Review of the Next Generation Air Transportation System: Implications and Importance of System Architecture.” That report was authored by another NRC committee and while our committee was aware of the general direction of that report’s findings while we were writing our review, the reports are independent.

Mr. Chairman, the transition of technologies into the National Airspace System and the generation of the associated procedures, regulations, and certification processes is a major challenge for the FAA. One of the problems is that improvements in avionics and other systems are occurring at a far more rapid pace than the procedures, regulations, and certification processes. Another issue is that avionics systems are becoming relatively cheaper whereas the certification costs are not. When the results of research are handed over for certification, a whole new process begins where the resulting new equipment must be designed, built, and then certified. Different functions of the FAA are required to be engaged in those processes—from airworthiness, to operational specification approval, to training, to certifying new air traffic procedures—and provide the interface with the industries producing hardware, software and the operators that use the system.

Certification of a new technology is not as important as the approval of the operational capability of that technology and its ultimate implementation in the National Airspace System. The many stakeholders play a major role in the introduction of new technology—from the airlines and other users buying, installing, training, and using the new capabilities, to the operators

of the National Airspace System having sufficient training, procedures, regulations, and policies to take advantage of the technology.

The users and supporters of the National Airspace System are a very broad mix—from airlines to the military to general aviation, the manufacturers of the air and ground equipment, and multiple labor and professional organizations—all with different and sometimes conflicting interests and expectations. The operation of the U.S. National Airspace System affects the lives of people around the world in terms of travel, commerce, and national security. This in turn presents the FAA with a complex and dynamic set of challenges. All of these users and stakeholders have a significant impact on the scope and type of research that the FAA must conduct.

Mr. Chairman, our committee found that the February 2014 certification research plan does not demonstrate how integration of aircraft, ground systems, and procedures will occur in the National Airspace System. In particular, it omitted any substantive discussion of the air segment. Although the FAA does provide a rationale for this omission, in the committee's view we do not believe that it is realistic to address one without the other because the air and ground segments are so closely integrated and will be even more integrated in NextGen. Successfully demonstrating how integration will occur will create confidence in implementation and, we believe, attract stakeholder and operator investment.

As I mentioned previously, the scope of our study was confined to the relatively narrow scope of reviewing a research plan for certification of new technologies. Our resulting major recommendation is that the FAA should

produce a new certification research plan—one that focuses on a number of important goals which I will now outline but which are discussed in more detail in our report.

Mr Chairman, our committee believes that all stakeholders will benefit substantially from the explanation of the end-to-end processes necessary to certify, approve, and implement advanced NextGen capabilities beyond the mid-term (that is, 5-7 years). It is in the best interests of the FAA that it describe and fully explain the steps that the FAA and aviation stakeholders are taking to expedite the realization of the NextGen capabilities. We believe there is value to the FAA producing a comprehensive research plan that explains the agency's research goals and plans for integrating and certifying technology into the National Airspace System. Future FAA research plans, when properly executed, can play a valuable role in guiding the FAA and stakeholders and explaining progress in certifying new technologies into the National Airspace System.

We also recommend that in its certification research plan FAA pay particular attention to several key issues including software assurance, cybersecurity, and verification and validation. Although we recognize that the FAA is aware of these issues, our committee believes that they are of such importance that they deserve constant attention and prioritization.

Finally, we recommend that a new FAA research plan on certification should benchmark the best practices of other organizations regarding certification that can contribute to the timely implementation of NextGen technologies. In our view a new FAA plan should outline how the agency

can best coordinate its research with other relevant organizations—particularly NASA, which conducts significant research of relevance on air traffic systems. We believe that these other organizations can provide valuable lessons to the FAA.

Thank you for the opportunity to speak to you about this National Research Council report and I look forward to addressing your questions.

WILLIAM S. LEBER, JR. is Co-Chair of the National Research Council's Committee to Review the Federal Aviation Administration Research Plan on Certification of New Technologies into the National Airspace System. He is senior vice president of Air Traffic Innovations for PASSUR Aerospace. His duties include strategy formation and strategic alliances with other companies, universities, and research organizations. He was formerly a research analyst principal and senior manager for Lockheed Martin in business development for their Collaborative Air Traffic Management Practice where he coordinated Lockheed Martin's efforts in airport collaborative decision making and other collaborative air traffic management domains. He has 25 years of air traffic management experience coordinating with the Federal Aviation Administration (FAA) and other air navigation service providers in the Atlantic and Pacific regions. He was a chief flight dispatcher and worked for Northwest Airlines and Delta Air Lines for more than 26 years. He is a member of the FAA Research Engineering and Development Advisory Committee (REDAC)-National Airspace System Operations Subcommittee, where he was co-chair of the Weather-Air Traffic Management Integration Work Group. He is a former chair of the Collaborative Decision Making Future Concepts Working Group and was co-chair of the Air Transportation Association's overall collaborative decision making effort from 2001 to 2004. He is a former president and co-founder of the Airline Dispatchers Federation, a non-union professional association. He holds a B.S. in aeronautical administration from St. Louis University and holds aircraft dispatcher and pilot certificates.

Chairman BABIN. Thank you, Mr. Leber.
I recognize Dr. Hansman for five minutes.

**TESTIMONY OF DR. R. JOHN HANSMAN,
T. WILSON PROFESSOR OF AERONAUTICS
& ASTRONAUTICS; DIRECTOR,
MIT INTERNATIONAL CENTER
FOR AIR TRANSPORTATION,
MASSACHUSETTS INSTITUTE OF TECHNOLOGY;
AND CHAIR, FAA RESEARCH AND
DEVELOPMENT ADVISORY COMMITTEE**

Dr. HANSMAN. Good morning. Chairman Babin, Ranking Member Edwards, and Members of the Committee, thanks for the opportunity to be here today to talk about research and its importance in aviation in the United States.

Research and development is vital to maintaining the safety, efficiency, environmental performance, and security of aviation in the United States and the rest of the world. The FAA oversees and operates the largest and most complicated National Airspace System in the world, and it needs R&D to maintain and improve the performance of the system.

As Chair of the REDAC Committee, I'll just mention some of the things that we have identified to the FAA of some of the strategic areas that we think are important. One that's been mentioned is the integration of UAS in the NAS. Another has also been mentioned, the efficient operational approval of new capabilities into the system to enable things like NextGen, so we have the technologies. We have to figure out how we actually get them operationally approved.

Human factors of increasingly automated systems as the Asiana accident represents, we have more automation in airplanes. We have to understand how humans interact with these things, both in the air and on the ground.

Data integrity and cybersecurity has also been mentioned. Cybersecurity is an emerging concern in aviation. It's been around for a long time. Some of the vulnerabilities may be overstated but this is clearly an important area for research.

There's also opportunities we feel to leverage Big Data. You know, the airspace system actually generates one of the nicest sets of data that's out there, and it gives us an opportunity to understand the dynamics of this complicated system.

Also, the other thing that the FAA needs to do is do research to be prepared to either use or approve new technologies as they emerge. For example, additive manufacturing, as we start to think about building airplanes with printing technology, do we have the understanding to make those approvals? Or the impact of portable devices, the iPhones and iPads that we all carry around, can change how cockpits and airplanes are operated, but there are systemic issues in terms of both vulnerability and how those would interact with the rest of the system, so we need to be doing research to support all those.

I'm happy to take any further questions or talk in more detail.
[The prepared statement of Dr. Hansman follows:]

Statement of

R. John Hansman, Jr.
T. Wilson Professor of Aeronautics & Astronautics and Engineering Systems
Director, MIT International Center for Air Transportation
Massachusetts Institute of Technology

before the

Committee on Science, Space and Technology
U.S. House of Representatives

June 11, 2015

Chairman Smith and Members of the Committee:

Thank you for the opportunity to comment on research and development issues which support "Transforming America's Air Travel." I am a Professor of Aeronautics and Astronautics at the Massachusetts Institute of Technology and the Co-Chair of the FAA Research and Development Advisory Committee (REDAC). The REDAC is a Congressionally mandated committee which advises the FAA Administrator on research and development. I should note that while my testimony is informed by my participation on the REDAC, due to time constraints my comments have not been coordinated with my REDAC colleagues so I am speaking as an individual today.

Research, Engineering and Development (RE&D) are vital to maintaining and improving the safety, efficiency, environmental performance and security of the aviation system in the United States and worldwide. The FAA has specific and unique RE&D requirements which come from it's oversight and operation of the National Airspace System (NAS) as well as it's role in regulating civil aviation in the United States. Research is required to improve the performance of the NAS, to be prepared to regulate and certify new vehicles and technologies as well as to respond to emerging challenges. The resulting research portfolio is very broad ranging from topics related to safety, airports, NAS operations, environmental impact, civil space and more.

As part of a recent strategic planning exercise the REDAC identified a number of emerging issues where it felt that research will be critical for the FAA. These include:

- Integration of UAS in the National Airspace System (NAS)
- Validation and Verification of Increasingly Complex NAS Systems
- Human Factors of Increasingly Automated Systems
- Data Integrity and Cyber-Security
- Challenges and Opportunities of Big Data in the NAS

- General Aviation Safety

In addition, some of the recent strategic observations that the REDAC has made and transmitted as advice to the administrator include.

Enabling the Potential of "Big Data" in the FAA - The growth of operational data and advances in data analysis open up exciting new approaches to better understand and improve the safety and efficiency of the NAS. The FAA has taken initial steps in this direction with data driven programs such as ASIAs and ADSI but there is significantly more potential. Realizing the full potential of "Big Data" will require development of data access policies which will allow the most open possible access to researchers and other users while protecting data confidentiality restrictions. The REDAC recommends that the FAA consider creative approaches to access policies such as multiple access levels to partitioned data structures. At the most open level the data could be fully open to the public enabling crowdsourcing and open competitions for students to creatively analyze and visualize

Emerging Human-Automation Issues - The increasing reliance on automation in aircraft and ATC systems have created emerging vulnerabilities in the aviation system highlighted by recent events. This was an important area of research during the initial introduction of highly automated aircraft such as the A-320 and B-767/757 in the 1970s but the character of emerging issues is changing. The REDAC recommends increased priority for human-automation interaction research and that the FAA work with related activities at NASA and the DOD.

Validating NEXTGEN Con-Ops - The key to successful delivery of NEXTGEN benefits will be to validate the Con-Ops currently under Concept Maturity and Systems Development at a sufficiently detailed level that operational feasibility can be assured and risks can be identified and managed. This includes definition of candidate operational procedures, addressing human factors issues (often in Human in the Loop Simulations) and considering operational issues such as mixed equipage and off-nominal conditions.

Mixed UAS and Manned Aircraft Operations - The committee appreciates the recent progress in UAS operational approval for small UAS but notes that the approaches for low altitude segregated operations do not address the larger UAS integration challenge. Many future UAS operations will require Con-Ops and procedures for mixed UAS and manned aircraft. This will be very challenging and the committee is concerned that the fundamental work to support this has been deferred or neglected.

Evaluating Community Noise Impact of Advanced Terminal Area Procedures - Community noise concerns with advanced PBN procedures at levels below the 65DNL threshold appear to be raising. This is a dual concern as it creates a barrier to implementation of NextGen procedures and creates pressure to revisit

noise metrics and evaluation processes. Research is required to improve the noise evaluation process, support a strong scientific basis for any metric adjustments and to enhance community involvement.

Opportunities for Cross Cutting Approaches - The REDAC notes that many emerging technical opportunities (e.g. Big Data Analysis, Cyber-Security, Human-Automation System Integration) impact multiple lines of business throughout the agency. There appear to be opportunities to take cross-cutting approaches in these areas.

Finally, I would note that it has been a challenge for the REDAC to maintain a comprehensive strategic view of the FAA research portfolio as research, engineering and development activities occur under different budget accounts and offices including: RE&D, Facilities & Equipment, Operations (NextGen), and the Airport Trust Fund).

Thank you for the opportunity to comment on the importance of research to the FAA and I am happy to answer any questions you might have.

Short Biography for

R. John Hansman

R. John Hansman is the T. Wilson Professor of Aeronautics & Astronautics at MIT, where he is the Director of the MIT International Center for Air Transportation. He conducts research in the application of information technology in operational aerospace systems. Dr. Hansman holds 7 patents and has authored over 250 technical publications. He has over 5900 hours of pilot in-command time in airplanes, helicopters and sailplanes including meteorological, production and engineering flight test experience. Professor Hansman chairs the US Federal Aviation Administration Research Engineering & Development Advisory Committee (REDAC). He is co-director of the national Center of Excellence in Aviation Sustainability Center (ASCENT). He is a member of the US National Academy of Engineering (NAE), is a Fellow of the AIAA and has received numerous awards including the AIAA Dryden Lectureship in Aeronautics Research, the ATCA Kiske Air Traffic Award, a Laurel from Aviation Week & Space Technology, and the FAA Excellence in Aviation Award.

Chairman BABIN. Thank you, Dr. Hansman.
Now I recognize Dr. Hyslop for five minutes.

**TESTIMONY OF DR. GREG HYSLOP,
SENIOR MEMBER, AMERICAN INSTITUTE
FOR AERONAUTICS AND ASTRONAUTICS;
VICE PRESIDENT AND GENERAL MANAGER,
BOEING RESEARCH & TECHNOLOGY;
CHIEF ENGINEER, ENGINEERING,
OPERATIONS & TECHNOLOGY,
THE BOEING COMPANY**

Dr. HYSLOP. Thank you, Chairman Babin, Ranking Member Edwards, and distinguished Members of the Committee. Thank you for the opportunity to testify about the importance of the Federal Aviation Administration's research, engineering, and development programs to our nation's continued leadership in aviation.

While I currently serve as Vice President and General Manager of Boeing Research and Technology, I'm speaking to you as a member of the American Institute of Aeronautics and Astronautics, the world's largest aerospace professional society serving more than 30,000 individual and 95 corporate members.

The FAA is of significant importance to AIAA, so I'm pleased that Congress is moving forward with legislation to extend the agency's programs. Reauthorization with adequate funding levels will ensure that our nation remains the world leader in aerospace innovation.

I've gained a great appreciation in my career for the important role that research and development plays in driving innovation. It is imperative that we continue to make strong investments in R&D. Wherever R&D goes, innovation and economic growth follow.

More than half of our economic growth is due to technological innovation, yet U.S. government R&D as a percentage of our GDP has fallen by 60 percent since 1964. In contrast, China's R&D investment is the fastest growing of all advanced countries and is forecast to overtake the European Union and the United States by the end of this decade.

It is important to note that when we fail to invest in new R&D programs, we risk losing talent and expertise that has taken us decades to cultivate and would be difficult to reconstitute. Our engineering talent is not a fixed asset. It is made up of people who need challenging new projects.

It also is important to note that declines in government R&D funding discourage young people from pursuing careers in science, technology, engineering, and mathematics. It is no mystery why U.S. engineering ranks were wide and deep in the 1960s and 1970s when U.S. R&D spending strong and the United States space program was prompting countless students to pursue STEM careers.

We are on the cusp of implementing a major advancement in transportation that could be just as exciting: a space-based air traffic management system. Creating such a system will have the same kind of impact on air travel that the Interstate Highway System had on surface transportation. The Next Generation Air Transportation System will enable more efficient airline operations and

yield annual cost savings in the billions of dollars. Now is the time for Congress to make strong financial commitment and set a firm timetable for NextGen's completion.

NextGen also is an integral part of the industry's plan for reducing airplane CO₂ emissions. Commercial aviation accounts for two percent of manmade carbon emissions, but that percentage will increase as air traffic grows unless NextGen is completed. According to the International Air Transport Association, cutting flight times by just one minute per flight would prevent 4.8 tons of CO₂ emissions every year. Sustainable biofuels are another important element of the industry's emissions reduction plan. Industry and government have partnered to create, test, and evaluate biofuels. As the supply of biofuels increases, their price will decline, spurring airline use. We've made good progress but still have a lot of work ahead of us. It is important that the U.S. government stay involved in the development of sustainable biofuels.

The third element of our industry's emissions reduction strategy is something the aerospace sector has been doing since its inception: developing ever-more-efficient airplanes. There are solid business reasons behind our work. Airlines always want greater efficiency. Now there are important environmental reasons as well for lighter, more aerodynamic airframes and more fuel-efficient engines. Government has important roles to play in these efforts so it is vital that Congress continues to fund long-lead research projects related to airframe and engine efficiency.

Finally, it is important that the FAA keep up with and enable the pace of innovation occurring in the aerospace sector. One program designed to maximize FAA resources is under study. Government and industry are researching how to move toward a systems engineering approach to airplane and engine certification. The end result of such a move would be a better, more efficient certification process, one that encourages innovation and accelerates the incorporation of innovative product enhancements.

Over the last century, the United States has been synonymous with global aviation leadership, and we can continue that legacy, but we cannot afford to rest on our laurels and simply say "remember when research and development was a national priority." The research programs at the FAA and NASA are critical to the work of the men and women of AIAA. The realization of NextGen, biofuels, more efficient jet engines, and lighter, more aerodynamic airplanes all require collaboration and partnership and a reliable stream of government investment in aviation's future.

Thank you again for inviting me to speak here today, and I look forward to discussing this topic with you further.

[The prepared statement of Dr. Hyslop follows:]



**Written Statement of
Dr. Gregory Hyslop
Senior Member
American Institute of Aeronautics and Astronautics
Reston, Virginia**

**Hearing of the
House of Representatives Committee on Science, Space, and
Technology Subcommittee on Space**

**“Transforming America’s Air Travel”
June 11, 2015**

Chairman Babin, Ranking Member Edwards, and distinguished members of the Committee, I thank you for the opportunity to testify about the importance of the Federal Aviation Administration’s (FAA) Research, Engineering, and Development (RE&D) programs to our nation’s continued leadership in aviation. While I currently serve as vice president and general manager of Boeing Research & Technology, I am speaking to you today as a member of the American Institute of Aeronautics and Astronautics (AIAA), the world’s largest aerospace professional society, serving a diverse range of more than 30,000 individual members and 95 corporate members.

Reauthorizing the FAA is of significant importance to AIAA members, so I am pleased that the Committee is holding this oversight hearing and that Congress is moving forward with the consideration of legislation to extend the agency’s programs. An extension, at adequate funding levels, will ensure that our nation remains the world leader in aerospace innovation.

Throughout my career in the aviation sector, I have gained a great appreciation for the important role that research and development (R&D) plays in driving innovation and progress. It is imperative that as a nation we continue to make strong investments in R&D. Wherever R&D goes, innovation and economic growth follow. More than half of the growth of our nation's gross domestic product (GDP) is due to technological innovation. Yet U.S. government R&D as a percentage of our GDP has fallen by 60 percent since 1964. By contrast, China's R&D investment is the fastest growing of all advanced countries. According to a biennial report by the Organization for Economic Co-operation and Development (OECD), China is forecast to overtake both the European Union and the United States in R&D spending by the end of this decade. China simply makes it a national priority as it attempts to compete, match, and surpass the United States in terms of economic prowess and military capabilities. To keep our technological edge, we must keep pace with growing investments by China and other nations. Our government must continue to promote innovation and competitiveness, strengthen our industrial base, level the playing field for U.S. companies and workers, and create a public infrastructure that is second to none.

It is important to note that when we fail to invest in new R&D programs we risk losing talent and expertise that has taken us decades to cultivate. Our engineering talent is not a fixed asset. It is made up of people who need challenging new projects. And if they do not have them, they move into other industries, choose to pursue other interests, or retire. Once lost, reconstituting this asset is very difficult and will take decades.

It also is important to note that declines in government R&D funding discourage young people from pursuing careers in science, technology, engineering, and mathematics—the so-called STEM disciplines. Less spending means fewer programs and therefore fewer job opportunities for college graduates. It is no mystery why U.S. engineering ranks were wide and deep in the 1960s and 1970s. U.S. government R&D spending was at its zenith then, in part because of defense programs, but also because of the space program that excited everyone and prompted countless students to pursue STEM careers.

We are on the cusp of implementing a major advancement in transportation that could be just as exciting to students and seasoned professionals alike—a space-based air-traffic management system. Creating such a system will have the same kind of impact on air travel that the Interstate

Highway System had on surface transportation. As many of you know, the Next Generation Air Transportation System (NextGen) will enable more efficient curved approaches to landing and give pilots the ability to adjust in real time to changing weather conditions en route so that they follow the most efficient path to their destination. It will reduce our industry's environmental footprint, save time and money, and contribute to achieving energy independence. The FAA's reorganized Joint Planning and Development Office (JPDO) has stated that NextGen improvements to ground operations at airports, in proximity operations around airports, and in the high-altitude cruise environment will yield annual benefits, or cost savings, in the billions of dollars.

Despite these potential benefits, NextGen has faced significant cuts and setbacks in recent years, causing some in Congress undoubtedly to lose faith in this modernization program. If we view NextGen as a financial investment for future generations, similar to how President Dwight D. Eisenhower viewed the Interstate Highway System more than 50 years ago, now is the time for Congress to make a strong financial commitment and set a firm timetable for NextGen's completion. The return on investment for the United States will be significant and lasting.

As mentioned, NextGen will help the aviation industry save fuel and thus reduce emissions. Completing the program, in fact, is an integral part of the industry's plan for reducing global airplane carbon dioxide (CO₂) emissions by 50 percent by 2050, compared with 2005 levels. Commercial aviation accounts for two percent of today's manmade global carbon emissions, but that percentage is on track to increase as air traffic grows unless NextGen is completed and other steps are taken—which I will address in a moment. According to the International Air Transport Association (IATA), cutting flight times by just one minute per flight on a global basis would prevent 4.8 tons of CO₂ emissions every year, so completing NextGen is key to the aviation industry's ability to meet its environmental targets.

Sustainable biofuels are another important element of the industry's emissions reduction plan. Boeing, Airbus, Embraer, and many others in the aviation industry, plus various government agencies, have partnered to create, test, and evaluate biofuels. As the supply of biofuels increases, the price of biofuels will decline and become competitive with petroleum-based fuel, spurring airline use. We have made good progress, but still have a lot of work ahead of us. It is important

that the U.S. government continues to stay involved in both the development and commercialization of sustainable biofuels.

The third element of our industry's emissions reduction strategy is something that the aerospace sector has been doing very well since its inception—developing ever-more-efficient airplanes and engines. There are solid business reasons behind our work in that area. Airlines have always wanted greater efficiency. Now there are important environmental reasons as well for developing lighter, more aerodynamic airframes and more fuel-efficient engines.

Government has important roles to play in these efforts. It is vital that Congress continues to provide funds for long-lead research projects that lead to more efficient airframes and engines. Another critical area is ensuring that the FAA is able to keep up with and enable the pace of innovation occurring in the aerospace sector. One program designed to maximize FAA resources is already under study. Government and industry have been involved in research and development necessary to move toward a systems engineering approach to airplane and engine certification. The end result of this research would be a better, more efficient certification process; one that encourages innovation and accelerates the incorporation of innovative product enhancements that make airplanes more efficient, safer, and more comfortable for passengers.

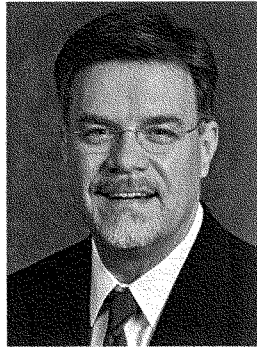
Over the last century, the aviation sector has improved our country and our world in countless ways. The United States has been synonymous with global aviation leadership—and we can continue that legacy. But it is going to take a commitment from all of us who care about sustaining U.S. leadership. Federal R&D investments are critical to this effort because they lead to innovation and technological advancement. The United States cannot afford to rest on our laurels and simply say “remember when” research and development was a national priority.

More than 30,000 men and women belong to AIAA. They come from industry, government, and academia. Many have been involved in some of aviation's great achievements, and all of them aspire to being involved in the next big breakthrough. Many of them also rely on government funding to support the work that they do. The FAA's Research, Engineering & Development budget and the National Aeronautics and Space Administration's aeronautics research program are critical to their work. The realization of NextGen, biofuels, more efficient jet engines, and lighter, more aerodynamic airplanes all require collaboration and partnership and a reliable stream of

government investment in aviation's future. Our nation's global leadership in this key industry is at stake.

Thank you again for allowing me to come speak to you today. I look forward to discussing this topic with you further, and to answering any questions you may have for me in this regard.

Executive Biography of Greg Hyslop, D.Sc.



Greg Hyslop, D.Sc.

Vice President and General Manager,
Boeing Research & Technology
Chief Engineer,
Engineering, Operations & Technology

Dr. Greg Hyslop is vice president and general manager of Boeing Research & Technology, the advanced central research and development unit of The Boeing Company. Hyslop leads a team of nearly 4,000 engineers, scientists, technicians and technologists who create and collaborate with R&D partners around the world to provide innovative system solutions and technologies to solve the aerospace industry's toughest challenges. Named to this position in February 2013, Hyslop has oversight of operations at five research centers in the U.S. including Alabama, California, Missouri, South Carolina and Washington, as well as six research centers in Australia, Brazil, China, Europe, India and Russia.

Hyslop also serves as the chief engineer for Engineering, Operations & Technology, the parent organization for BR&T. In 2015, he assumed the additional role as the enterprise engineering leader, partnering with chief engineers for other Boeing business units to ensure One Boeing solutions that support programs across the enterprise. He also plays a key role in decisions that affect the technical integrity of Boeing products, services and processes.

Prior to his BR&T role, Hyslop served as vice president and general manager of Boeing Strategic Missile & Defense Systems (SM&DS) for four years. He led the SM&DS team to deliver integrated solutions for missile defense, strategic missile systems as well as several directed energy technologies and systems.

Hyslop also has held Boeing leadership posts with the Ground-based Midcourse Defense program, the Airborne Laser program and the Special Projects-Dallas team. In addition, he supported a number of cruise missile programs including Tomahawk, Harpoon, Standoff Land Attack Missile (SLAM) and

Standoff Land Attack Missile – Expanded Response (SLAM-ER) since joining the McDonnell Douglas Astronautics Company, now part of Boeing, in 1982 as a guidance and control engineer.

Hyslop has a Bachelor of Science degree in electrical engineering from the University of Nebraska, a Master of Science degree in mathematics from the University of Nebraska, and a Doctor of Science degree in systems science and mathematics from Washington University in St. Louis, where he also served as an adjunct professor.

Chairman BABIN. Okay. Thank you, Dr. Hyslop. I appreciate that. And I thank all the witnesses for your testimony, and I recognize myself for five minutes.

This question is for Mr. Filler and Dr. Shin. Since 2008, Congress has provided more than \$1.5 billion in developmental projects intended to explore new concepts and evaluate alternatives to reduce uncertainty and risk associated with NextGen programs. However, unlike major acquisition programs, these projects do not have formally approved cost and schedule milestones and do not receive the program oversight given to other procurement programs. Last year, the Department of Transportation's IG Office testified that the initial 2004 estimates of \$40 billion shared equally by the public and private sectors could double or even triple. The IG's Office also warned that the initial 2025 implementation date could slip by as much as a decade. Just this week, the IG announced a review of NextGen.

In lieu of cost and schedule milestones, how do FAA and NASA ensure that this effort is on budget and meeting its objectives? Dr. Shin or Mr. Filler, whichever one of you would like to go first.

Mr. FILLER. NASA and FAA do coordinate through a variety of forums. In our research efforts—Dr. Shin is a member of our R&D Advisory Committee—the program he mentioned earlier, the ASTS, we also work on research efforts in that forum. We routinely receive products and technology transfers through the Research and Technology program, the RTTs, and integrate those into NextGen planning. NextGen is not a static plan that has a finite destination. It is constantly evolving as time progresses, demands change, and likewise we adapt our programs. But NASA and FAA do coordinate routinely, if not quarterly, I'll say monthly, through a variety of forums and throughout all our many, many levels in the agency to make sure that we are constantly in sync with each other.

Dr. SHIN. Yes, Chairman. Thank you for that question. NASA, as I mentioned in the oral testimony, is the organization that develops enabling revolutionary technologies, so we are indeed our country's depository for research and development for all types of aeronautics technologies. So in particular, on the air traffic management and safety side, we are heavily coordinating with FAA, and in fact, my perspective is, FAA is the most important customer for NASA in the civil aviation side and DoD is the most important partner for us in dual-use technologies.

So as Dennis Filler just mentioned about RTTs and also I mentioned in the opening testimony that it is a big change for NASA and FAA to work together through this RTT.

I can share stories from maybe ten years ago. We used to develop NASA technologies in hoping that FAA will incorporate and implement that. Sometimes it works, sometimes it didn't work because we didn't have the coordination and collaboration from day one. So we changed that, and that's the essence of our research transition team, as I mentioned. So we coordinate from day one that FAA air traffic controllers, managers, technical people work together to devise the research plan together and update and refine.

So just one quick example is that EDA, we call Efficient Descent Advisor. This is the technology that allows aircraft to have a continuous descent without throttling up and down and following the

path that is somewhat of a reverse wedding cake, if you will. So that saves a tremendous fuels and also reduces community noise. So that type of technology could save \$300 million per year in fuel savings if the technology is implemented across fleet and airports. So that's the kind of impact research that we are doing with FAA.

Chairman BABIN. Thank you very much. I appreciate that.

Our Ranking Member, the gentlewoman from Maryland, Ms. Edwards, is going to allow the gentleman from Virginia, Mr. Beyer, to ask the first question, and I understand you have to leave, so I'll recognize—

Mr. BEYER. Thank you, Mr. Chairman, and thank you, Ranking Member Edwards.

Mr. Filler, I understand the FAA is starting work on a multiyear effort to update the scientific evidence on the relationship between aircraft noise exposure and its effect on communities around airports. This will be done by contacting residents by phone, by mail, and it's indicated that you'll not disclose which communities will be polled to preserve the scientific integrity of the study. According to FAA, a key goal of the survey is to determine whether the agency should reevaluate the noise metrics that it uses, and while I appreciate the need for scientific evidence, I remain incredibly concerned about the nature of the citizen complaints about the aircraft noise that is not being well understood.

I represent National Airport, and we hear this every day. As you know, aircraft noise is currently measured on a scale that averages all community noise during a 24-hour period with a tenfold penalty on noise that occurs during night and early morning hours. Now, all this methodology works if you're looking for a long-term average noise level. It doesn't help if you're trying to measure the noise impact of a plane that's flying over your house. In that type of situation, you want to find a way to measure peak decibel level and frequency.

So Mr. Filler, my question is, how will the study address those concerns, you know, the inability to have a picnic in your backyard or have a conversation on your front porch?

Mr. FILLER. Sir, I know that these considerations are being evaluated right now in the FAA's Environment and Energy program. Specifically, I can't answer your question directly. I don't have the technical expertise personally in this domain but I can assure you we'll be glad to take the question back and get you a more thorough answer.

Mr. BEYER. All right. Thank you very much.

Dr. Shin, is NASA doing any research on reducing aircraft noise? What can we look forward to in the future?

Dr. SHIN. Yes, that is one of our main research topics at NASA, as you point out, because the community noise is a big issue around the world, not just U.S. airports, and our issue is more acute because all the major airports in the United States are land-locked. So we have all the houses around the airports. And to compound the problem, as the Congressman accurately pointed out, it is a perception issue as well. So it's not entirely scientific approach. So there is an international noise measurement standard, so we are following that to reduce the noise, but still, there is a strong concern about communities around the airport with airplanes fly-

ing over their houses. So we are working both from operational procedures. So how can we effectively route airplanes around the communities to land safely but with less noise? That's part of that EDA that I talked about, Efficient Descent Advisor. So operational side, we work on that, but also vehicle side, engine noise. We have just—actually Boeing should take credit to put that Chevron nozzle which reduces the engine noise substantially. So we are working on also aircraft technologies to reduce noise.

Mr. BEYER. And the Boeing headquarters is right next to National Airport, so they're motivated.

Dr. Hyslop, yesterday the EPA announced that it's going to try to regulate the emissions from airplanes. Aviation is one of the fastest growing sources of greenhouse gases right now. What are we doing technologically and operationally to reduce the emissions from our aircraft?

Dr. HYSLOP. Thank you, Congressman. And the committee—or the company is very committed to reducing emissions of aircraft because we recognize we have that responsibility. There's a number of technologies that are in work, and I can highlight several. Dennis talked about the CLEEN program, which is a program we have done in conjunction and partnership with the FAA where we look at not only aerodynamic efficiencies to reduce fuel burn. We look at different materials. We just completed a flight test last year with a different kind of engine nozzle out of a ceramic material that will address acoustics. We've done a significant amount of work in biofuels looking at various forms and sources for where those biofuels come from, and since the number one cost of operating an airliner is still going to be fuel, there is a constant drive from us and the engine companies to become more and more efficient all the time, which is really why things like the 787 Dreamliner and what really drove a lot of those technologies behind those aircraft and will continue to drive them into the future.

So between aerodynamics and biofuels and new materials that would enable those, there's significant work underway in conjunction with FAA and NASA.

Mr. BEYER. Thank you, Doctor, and thank you, Mr. Chairman. Thank you, Ms. Edwards.

Chairman BABIN. Yes, sir. Thank you, Mr. Beyer.

And I'd like to now recognize the gentleman from California, Mr. Knight.

Mr. KNIGHT. Thank you, Mr. Chair. I appreciate seeing Dr. Shin here today. It's always good to see you and hear your testimony. I have a couple questions about where we are and where we're going to be in the next ten years as far as airliner flight. You know, it seems like for the last 40 years, we've almost been stuck in the mud. In 1970, if I went to go across country, it probably took me 4-1/2 days. Today it takes me 4-1/2 hours. We're much cleaner, we do this more economically but we are a little bit stuck technologically.

I know that NASA has done many programs. Back in the early 2000s, you did a Quiet Spike program that worked on dispersing the sonic boom and making it so maybe we could travel across the country supersonic at some period of time. Is that something that NASA is still working toward? Is that something that maybe the

private industry—we have about 20 billionaires out there that are just driving to become millionaires by getting into the aerospace and space industry. Maybe we want to incorporate some of them too to look at this.

Dr. SHIN. It's good to see you again, Congressman Knight, as well. Thank you for that question, because the speed will become important. As Chairman and both Ranking Member mentioned about growth in Asia Pacific region in mobility and the distance, as we call it, tyranny of distance, will become important factor in aviation. So to that end, we have been working—NASA has been working in developing low-boom supersonic flight technologies. The focus on low boom is because currently we have a law internationally and also in the United States that doesn't allow supersonic flight over land. So unless we change that rule to certain—meeting the certain target rather than complete ban, the private industry I highly doubt will jump into this venture. As you pointed out, there are many interested private industry partners who would like to see this new capability. So that's where NASA is focusing, trying to develop scientific database that by design we can actually build low-boom supersonic airplane, not through some kind of gimmicks but actual design, and then provide that database to FAA and international rulemaking agencies, organizations for their consideration to change the rule. Then I think our industry's ingenuity and the agility will provide that opening up the new capability.

Mr. KNIGHT. Thank you.

And Dr. Hyslop, I've worked with AIAA. It's a great organization. You hit me with one of the comments that you made about our STEM students and our engineering students and maybe we're not as like we were in the 1950s and 1960s. I think that part of it is the advent of computers, that computers are very cool today, and a lot of our engineering students are going into that type of field as opposed to in the 1950s and 1960s they went on to aeronautical engineering or something like that. Where do you think we're dropping the ball on this? Because I don't know any Congressman or legislator out in the States that don't talk about STEM? It is the buzz phrase today. It is what we want. We are seeing the jump in young ladies being involved in engineering. I would venture to guess in 1960, if you were a young woman and you were becoming an engineering student, you were one in a thousand. Today you're probably one in five. So we've made huge advancements in that, and those are just my—don't look those up but I'm betting that they're a lot closer. So where are we dropping the ball on this?

Dr. HYSLOP. Well, that's a very good question, Congressman. I think—I was at a STEM event with fifth graders in Houston a few weeks back, and we have to communicate to them the excitement that comes from aerospace and working on these kind of products and being part of these kind of teams and bring these products to life. But I think you really—instead of focusing on the student, we really have to focus on the teachers, and we probably need to focus on the families that support the student because unless you take a full rounded view of that to make sure the teachers are comfortable teaching STEM-type subjects at very low levels and that the families know where to get—if they can't provide the support,

they know where they can get help to help them support that student as they're going through those courses.

In my opinion, I think it's—we may be too focused on the student and not enough on the faculty and on the families so that we've got a more balanced approach to the whole issue.

Mr. KNIGHT. I appreciate that very much.

Mr. Chair, I yield back.

Chairman BABIN. Yes, sir. Thank you, and well stated.

I'd like to recognize the gentlewoman from Maryland, Ranking Member Ms. Edwards.

Ms. EDWARDS. Thank you very much, Mr. Chairman, and again, thanks to the witnesses.

Just a comment on the last discussion with—about STEM. The American Association of University Women just this last week, just a couple of days ago, released an amazing report about women and girls and their participation in STEM fields, and the problem that we're seeing really begins in about first grade where for a variety of reasons, girls make a decision very early on that they are not science and math students. And so we have to disengage from that. But the problems that actually continues—the problem continues through the lower grade levels, and then even into college and even in the workplace. Once a woman is in as an engineer, there're a variety of factors that lead to her making a decision that that's not for her. And so we have a lot to do because the fact is that we are—according to this AAUW report, we are losing a significant portion of our economy precisely because women and girls are not engaged in the STEM fields, and the 21st century, frankly, is all about that, whether it's in aviation or others of our R&D fields. And so, if there's some point at which we can have a hearing and really discuss the factors that are leading to that and how we can more greatly engage women and girls, that would be a good conversation. And the problem is particularly acute for students of color, and so we've got a lot to do. Otherwise we're going to lose a major part of our workforce.

Mr. Filler, I want to go back to this issue of the plan that was supposed to be transmitted to the—by the President to the Congress 2014 and 2015, because this is very problematic. We're trying to look at how we engage in this next generation of technology for aviation but we don't even get the benefit in the Congress of a plan that's required by statute, not in 2014 and not in 2015. And so can you give us a definitive date by which we can expect what has been due since 2014?

Mr. FILLER. Yes, ma'am. As far as a definitive date, I can tell you that both plans have left the FAA. The delay was because we totally restructured both of these plans, and subsequent to that, the internal coordination required to clear the plans took much longer than what we ever anticipated. I can assure you that we have in fact started on the 2016 plan.

Ms. EDWARDS. Wait. Congress would like to see 2014 and 2015 before we get to see 2016.

Mr. FILLER. Yes, ma'am, both 2014 and 2015 have left the Federal Aviation Administration.

Ms. EDWARDS. Okay.

Mr. FILLER. Okay?

Ms. EDWARDS. I hear what you're saying. I guess I'm trying to figure out where we should drive to pick it up and when it's going to be delivered to Congress, and I don't mean to be flippant about this but when we've required something by statute, it's precisely because we need that in order to be able to make an assessment about what we're doing on resource allocation and whether plans are going according to plan.

I mean, one of my frustrations, frankly, has been since that I've been on this Committee and in Congress, we've been talking about NextGen as though it is going to be a transformation of the industry, and yet what we're hearing sounds much more like it's a little tweak here and there, a couple of upgrades not a transformation.

Mr. Leber, I'm a little bit curious about the nature of your testimony because you focus very specifically on the limited scope that you had as the Academies. How should your work and analysis really inform what it is that we're doing?

Mr. LEBER. Thank you, Congresswoman. I encourage the Committee to read the report thoroughly. We clearly had challenges getting information, and so we—it took a while for the FAA, first of all, to produce the report. Then we had—we had asked for speakers at some of our earlier meetings. We were unable to obtain them. Ultimately, we did have those speakers address the committee, and we appreciated that. But it was clear to the committee that this research report was not given the priority we thought it deserved as something that the Congress specifically asked for in the reauthorization.

Ms. EDWARDS. Do you think that there's a gap in terms of the FAA and NASA understanding the value of the Academies in informing how we go forward?

Mr. LEBER. Through the course of our investigation, NASA's work with the Academies was cited repeatedly as exemplary and effective. But yes, in answer to your question, Congresswoman, it appeared to us that there was a significant gap in the way the agency, the FAA, interacts with the Academy and the way NASA interacts.

Ms. EDWARDS. Well, thank you, Mr. Chairman, and I hope we can explore further about the way that we close that gap because the Academies play an important role in us figuring out the direction and the critical analysis that needs to take place in terms of how we develop our R&D capability.

Thank you, Mr. Chairman.

Chairman BABIN. Okay, and I'd like to recognize Mr. LoBiondo, the Aviation Subcommittee Chair on the Transportation and Infrastructure Committee.

Mr. LOBIONDO. Thank you, Mr. Chairman.

My question is for—questions are for Mr. Filler. With cybersecurity being today and increasingly becoming extremely critical for us as a nation, Dennis, can you tell us what is the Tech Center doing today? What can it be doing additionally? What should it be doing additionally to help deal with this cybersecurity problem? And then I have a UAS question if you—depending on the time that's left.

Mr. FILLER. Thank you, Congressman. In the realm of cyber, currently we are working on research initiatives looking into the certification of aircraft technologies with cyber implications, how to

take in and understand the current means and methods that are being employed, how software is developed, and then likewise how they are in fact tested and certified for use onboard aircraft systems. So that is ongoing research that is happening.

Recently, we have built a cyber test facility—we call it the CyTF—at the William J. Hughes Technical Center. Since we have the capability of every operational development system within the National Airspace System, we are going to use the CyTF to look at new and emerging vulnerabilities and threats to existent and developmental NAS systems.

Likewise, please keep in mind that every system that goes into the National Airspace System has as part of its foundational building blocks cyber concerns already built in to every platform. Cyber is not a static threat. It is dynamic and therefore it requires continuous evaluation and research to make sure that we can counter these emerging or zero-day threats, things that we haven't seen before. What we're doing is actually turning the entire Technical Center into a cyber test facility where we can attack each of our representative systems with various threats to be able to find out how our systems respond and then what countermeasures we have to develop and put into our system to be able to counter what is a very dynamic situation.

In the future, we need to continue to work in large technologies from DoD, from DHS, and anywhere else through cooperative research and development agreements and make sure that we continue to adopt these technologies and apply them because that's what FAA research is all about: applying technologies that are out there commercially or developed through other governmental agencies that have the leads in many of these areas to make sure that we are continually ensuring that aviation remains safe and secure.

Mr. LOBIONDO. So is it safe to say that for the FAA, the Tech Center is the tip of the spear for cybersecurity issues?

Mr. FILLER. Yes, sir.

Mr. LOBIONDO. A follow-up question is, there's a lot of excitement and a lot of discussions about the UAS integration into the national airspace. Can you tell us what the FAA Tech Center is uniquely qualified to do in relationship to UAS integration?

Mr. FILLER. On UAS integration, we have a UAS laboratory, and it has many representative UAS systems. We have every system within the NAS, and so we are in fact exploring integration of UAS into the NAS by using very advanced simulation technologies to interact with existing elements of the NAS and then also future concepts.

So just last year, we completed a very extensive test program with the Department of Defense on integrating their UAS into operation in the National Airspace System. It was a very detailed, very exhaustive, very thorough simulation that went through many domains of flight and looking at ways that for example, the Department of Defense can safely integrate UAS and use them in the National Airspace System. We use a very exhaustive test methodology to test various proofs of concepts and see what works and what doesn't work to assure that we have continued safe integration of UAS.

Mr. LOBIONDO. Thank you, Mr. Filler.

Mr. Chairman, thank you for the opportunity to sit on the Committee, and as our Committee moves to the actual presentation of the reauthorization bill, we look to you for a close working relationship in a very bipartisan way with your Committee and the Science Committee to move forward. Thank you very much.

Chairman BABIN. Yes, sir. Thank you very much for visiting this morning and your line of questioning.

And also we have—I'd like to recognize at this time the gentleman from Texas, Mr. Veasey.

Mr. VEASEY. Thank you, Mr. Chairman. I appreciate everybody being here today, and I wanted to ask Dr. Shin a question because I know that UAS integration into the NAS is an important facet of your work, and how does NASA's work contribute to FAA's ability to regulate future UAS operations?

Dr. SHIN. Yes. Thank you for that question, Congressman.

We have started UAS integration into NAS project about five years ago, so we have been developing, as I mentioned in the opening statement, the sense-and-avoid technologies, also communication and human-machine interaction, and we're also building live virtual constructive test environment to test all the technologies. So we have been heavily involved in the rulemaking by supporting technical data and knowledge and technologies so that FAA and RTCA can make the rules within capabilities of the system. So that's what we have been working in very close partnership with FAA.

Also, we have initiated last year for helping the community to allow safe and routine access of the small UAS at the much lower altitude, perhaps below 700 feet. That's where a lot of commerce interest is, as we've been hearing on the news media. So our role again is trying to provide enabling technologies and in partnership with FAA to allow these operations in a safe and effective manner.

Mr. VEASEY. And something else I wanted to ask you too is, how do you envision leveraging the research results from both the COE for UAS and the FAA test sites?

Dr. SHIN. Yes. Our project manager for UAS integration into NAS that I just mentioned has visited and his team has visited all six FAA UAS test sites, and we are evaluating what sort of partnership and collaboration is possible, and as I mentioned, we are also developing that live virtual constructive test environment where we can actually insert virtual aircraft, manned or unmanned, also with manned aircraft, and we can do these tests at multiple sites across the country. So that's why we call it live virtual constructive environment.

I think there's a great potential for NASA to collaborate with these UAS test sites using that framework and so we are actively looking into all possibilities.

Mr. VEASEY. Okay. Thank you very much.

My next question is for Dr. Hansman. Regarding the mixing of unmanned aircraft systems and manned aircraft operations, you indicate in your prepared statement that the future UAS operations will require formal concepts of operations and procedures for such mixing to occur. Specific to that research, you say that the REDAC is concerned that the "fundamental work to support this has been deferred or neglected." Can you elaborate exactly on what type of

fundamental work has been deferred or neglected and the implications of FAA not supporting this research?

Dr. HANSMAN. Sure. So there are multiple classes of UAVs that have different requirements, so as Dr. Shin mentioned, there's a lot going on at the low altitude—low-altitude small UAVs. There is a current rule out for line-of-sight operations. There's work being done at NASA beyond line of sight. The bigger challenge actually occurs when you have slightly larger UAVs that want to operate in the airspace that manned airplanes want to operate on, and there's really—it's not clear what the right procedures are going to be. Are you basically going to treat them as manned airplanes, IFR targets, and have to operate under those rules? What happens when the operator loses communication with the UAV? What are the procedures and things like that?

So this has been an area that's actually fundamentally hard, and people have been sort of doing the easy job, doing the low-altitude job, and they haven't really dug in on the fully integrated UAV and the NAS. So that was the particular we're worried about.

Mr. VEASEY. Thank you. Thank you very much. My time has expired. Mr. Chairman, I thank you.

Chairman BABIN. Thank you. Thank you very much.

I think we'll go back through one more time a line of questioning, and I would like to follow up with a little bit that has already been talked about somewhat. We're aware of many recent reports that individuals claim to have been able to hack into airline inflight entertainment systems, taking control of aircrafts' flight control systems, and while these claims may be greatly exaggerated, again, if you'd elaborate more than a while ago, what is FAA, NASA and the industry doing to prevent this from happening? This is for Mr. Filler, Dr. Hyslop and Dr. Shin.

And to follow that through, do you believe that government is doing enough? Because I noted in Mr. Leber's report that NRC has mentioned that cybersecurity should be more of a consideration.

Mr. FILLER. Sir, the—

Chairman BABIN. Mr. Filler.

Mr. FILLER. Thank you. The FAA takes the cybersecurity threat very seriously. As I mentioned earlier, yes, we do have active research ongoing looking at the increasing interaction of automation systems onboard the aircraft and the use of interconnected electronics. As systems become more and more connected, the interaction effects provide opportunities for new threats to emerge and be able to have vulnerabilities exposed. We are looking to make sure that there are no vulnerabilities, so as the threat changes, we're working with all of the agencies involved to include intelligence agencies on how these emerging threats are coming out and making sure that our current airframes and systems are maximally protected. Again, though, it is a very dynamic and a very challenging problem—it's not that you get to point X and you are done. It's ongoing just as each of us are equally aware of, we apply patches to all of our computer operating systems daily if not at least weekly. Likewise, we'll have to make sure that all of our systems are fully secured. So right now we do have very active, ongoing research to make sure that these threats are not posing any risk to aviation, and to date, we've demonstrated very safe and efficient

flights throughout the National Airspace System. So, thus far we've been able to do a very good job.

Chairman BABIN. Thank you, Mr. Filler.

Dr. Hyslop?

Dr. HYSLOP. Yeah, Congressman. There's close collaboration across the industry to ensure the entire aviation system is secure from a cyber perspective, and the best practices and threat information is shared amongst everyone on a regular basis.

Speaking now for my company, in the United States, Boeing has led the establishment of an Aviation Information Sharing Analysis Center. Members include Airbus, nearly all U.S. domestic airlines and Air Canada and a number of other non-U.S. airlines as well as airports are considering membership. This group receives regular cyber threat briefings from all the appropriate agencies and the FAA plus members are able to rapidly share emerging threats as they see on their own networks with each other. So there's significant amount of interaction amongst industry and the governments on this important issue.

Chairman BABIN. Okay. Thank you.

And Dr. Shin?

Dr. SHIN. Yes. Only a couple points to add. As we are introducing, as the Chairman pointed out, introducing more autonomous systems and more software-laden systems in the airplane, NASA is also working on verification and validation to help industry to develop the software, not only cost-effectively but also safe and secure, and we develop a lot of software as well for control systems or other aircraft systems, so we are also ensuring that our technologies will be secure and safe. That's one point.

But the second point is, through that interagency planning office that FAA's running in place of JPDO now has Homeland Security as a member, and so the overall and coordinated effort led by Homeland Security Department working with FAA and other federal agencies and industry, as Dr. Hyslop mentioned, I think we are doing everything we can to make airplanes safe.

Chairman BABIN. Thank you, Dr. Shin.

And also, since the report was so critical, I'd like to let Mr. Leber have an opportunity to give us his view there.

Mr. LEBER. Thank you, Mr. Chairman.

We had a specific focus on confidence and timeliness of implementing things in the National Airspace System. We went through various aspects of the report, but there was a clear gap there, and it was not clear to us in the report itself, the 10-page research plan, that this issue was being adequately focused on. So we called it out in our recommendations.

Chairman BABIN. Okay, sir. Thank you.

And I'd like to go through one more time here and recognize the gentlewoman from Maryland, Ranking Member, Ms. Edwards.

Ms. EDWARDS. Thank you very much.

I want to follow up with Dr. Hansman from the earlier line of questions. What are the implications of not having the research plan available for several years now?

Dr. HANSMAN. So in terms of the NARP plan as—

Ms. EDWARDS. Yes.

Dr. HANSMAN. So within the REDAC, the internal elements have actually been briefed to the REDAC so there has been internal communication. So I think that from that standpoint, there hasn't been a problem.

There was a bit of a problem, which I indicated in my report, in that there are multiple lines of funding where research is funded within the FAA. So there's the R&D budget, there's also F&E budget, airports, NAS ops. It's actually very difficult for us as the REDAC, and I actually think for the agency itself, to maintain a strategic view of its research portfolio because it's carved into different pieces and there is clearly stovepipes within the agency within different parts of the agency. So I do think that's a challenge for the agency itself and then for advisory committees like REDAC.

Ms. EDWARDS. And so then that leads to the next question. What do you think are the key issues and research areas that the Committee ought to prioritize in the R&D section of FAA's next reauthorization, and why?

Dr. HANSMAN. Well, this is now into the personal opinion. I think that the expectations on REDAC or expectations on NextGen are somewhat out of whack with reality and probably always have been. I think that one of the things that's not appreciated is how difficult it is to make improvements to a system which is incredibly safe and actually reasonably efficient. So the real challenge we have is, we have the technologies. There's no question we have ADS-B, we have all of the ground technologies. We sort of know what to do in the technical side. We actually have ideas on what the—how we should operate but unable to get those approved in a way that you can guarantee that we won't degrade the safety of the system is an incredible challenge, and I think that's why the report that Bill talked about, the intent of the Congress was to try to push the FAA to really think about that. I think that there is some institutional resistance to do that, and I think it's well intentioned. They want to maintain the safety of the system. They don't want to be pushed. They don't want to do things that take risk. And safety is the number one priority. So I think—

Ms. EDWARDS. Because you're talking about developing not a parallel system but integrating these new technologies into an existing system.

Dr. HANSMAN. Yeah, you have an existing system that flies every day, 24 hours a day, that has accident rates that are unprecedented in any level of transportation. So when you come in with some whacko new technology that someone wants to put in and say well, you know, let's do this, the FAA legitimately says well, wait a minute, okay, we need to do that. So do they have the—that's part of the reason for the importance of the research. They have to have done enough research so that they can say no, no, you can't do that for this reason. They also need to think about are there process ways that would allow them to test the technology, start to bring it in, in some evaluation way that would allow you to get it into the system faster than ten years from now, 20 years from now.

Ms. EDWARDS. Mr. Leber, do you have a perspective about that or about other areas of R&D that should be prioritized?

Mr. LEBER. Well, Congresswoman, I'm not sure I can improve on John's eloquent expression there. I think it was spot on. But I will just say that we have a cultural challenge, not a technological challenge. We have a communications, maybe—well, a communications challenge, I think. So we need to find ways to overcome the goodness that the FAA brings in its absolute vanguard of safety. They are beyond successful. And that goes for the entire industry, not just the FAA. But we need to overcome our communications and cultural resistance to change because the world is going to change and we're going to have to change aviation with it if we're going to lead.

Ms. EDWARDS. And then Dr. Hansman and other witnesses if you want, do you have a perspective on the extent to which the NextGen office I guess as a coordinating kind of entity is effectively carrying out its joint planning responsibilities? Is there another balance that needs to be struck?

Dr. HANSMAN. I think the NextGen office is actually— with its current administration has actually been doing a pretty good job. They—because of the pressure and because of the fact that NextGen is behind and hasn't delivered, as you guys have indicated, have shifted to a short-term focus. So it's—these are the things. They've clearly prioritized the things so that—that are short term to get something on the table, get some results.

I do have a concern that you then start to lose some of the long-term focus, so you're not investing on the things that we need to do in the future or emerging opportunities or issues. So that would be the concern.

Ms. EDWARDS. Yeah. I mean, I guess my concern as I expressed earlier is that sure, you do these short-term things but then it becomes a sort of system that's about upgrading as opposed to transforming.

Dr. HANSMAN. Yeah, I just—if I could, I think the reality was, it was always going to be an upgrading instead of transforming, that the expectations at the beginning were probably unrealistic. They were aspirational, and given the reality of implementation, the challenges of implementation, I think it's—they have to do this really on a worldwide basis, that some of the ideas were probably a little bit aggressive. So I think that—and part of this is, we can't shut off the system. We have to run. So I think we actually have to figure out how to do effective, highly leveraged transitions of the existing system that will really improve the performance where you need it.

Ms. EDWARDS. Thank you very much. Thank you, Mr. Chairman.

Chairman BABIN. Yes, ma'am. Thank you.

I'd like to—oh, the gentleman from Texas is gone too and so is the gentleman from California. So we will—if there's anything else—is there anything else we need to do?

I want to thank the witnesses for being here, for your testimony, and for your questions of folks here, and the record will remain open for two weeks for additional written comments and written questions from other Members.

So without any further ado, this meeting is adjourned. Thank you.

[Whereupon, at 10:27 a.m., the Subcommittee was adjourned.]

Appendix I

ANSWERS TO POST-HEARING QUESTIONS

ANSWERS TO POST-HEARING QUESTIONS

*Responses by Dr. Jaiwon Shin***HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
SUBCOMMITTEE ON SPACE*****“Transforming America’s Air Travel”***

Dr. Jaiwon Shin, Associate Administrator, Aeronautics Research Mission Directorate, NASA;
Member, FAA Research and Development Advisory Committee

Questions submitted by Rep. Brian Babin, Chairman, Space Subcommittee

QUESTION 1:

Our committee requested that NASA provide a budget cross-walk of the programmatic changes under the Aeronautics Research Mission Directorate's (ARMD) budget from FY 2014 through FY 2015 to FY 2016 in several occasions. During the March budget briefings, NASA promised to provide this information. In discussions with Associate Administrator Shin prior to this hearing, NASA once again promised to provide this information. Yet, NASA still has yet to get this information to Committee staff. Please provide a detailed budgetary analysis of programs submitted in FY 2014 and FY 2015 and how/where their funding now resides in the reprogramed FY 2016 budget.

ANSWER 1:

The FY 2014 restructure crosswalk with the FY 2016 President’s budget added is attached. Also attached is a color coded crosswalk.

QUESTION 2:

The automation of air traffic control (ATC) systems is raising new human-automation interaction vulnerabilities. What research and development activities, are addressing air traffic control human-automation interaction vulnerabilities?

ANSWER 2:

Advanced human-automation interaction research is conducted broadly across the Airspace Operations and Safety Program. All activities in the Air Traffic Management (ATM) Technologies Demonstration Project conduct rigorous human factors studies to ensure that any human-machine interaction vulnerabilities are exposed and mitigated at early stages in the development process. In the Safe Autonomous Systems Operations project, complex automation systems and autonomous operations for future NextGen states are explored to assess emerging human-computer interactions.

QUESTION 2a:

How is NASA coordinating with DoD and NSF on human-automation research?

ANSWER 2a:

NASA actively participates with DoD, NSF and other agencies (NIH, DoE, NIST, etc.) in the Cyber Physical Systems (CPS) community and programs. NASA is a member of the CPS Senior Steering Group and has many researchers and engineers participating in various working groups, conferences, studies, and joint efforts focused directly on the benefits, challenges, and risks of advanced human-automation research. NASA is currently participating in a joint solicitation led by NSF on CPS topics including human-automation research. This community also has significant academic and industry participation that ensures the appropriate situational awareness of the state-of-the-art and provides real-world feedback on mission priorities, business case requirements and policy and legal challenges in this area. In addition, NASA is currently collaborating with AFRL and DARPA to explore technology applications for reduced crew operations and the human-automation challenges that must be addressed.

QUESTION 3:

What is NASA's aeronautics research plan for future research and development?

ANSWER 3:

NASA Aeronautics Research Mission Directorate (ARMD) has spent the last 2 years defining its research strategy and vision for aeronautics research. The ARMD strategy has been documented in the Strategic Implementation Plan which can be found at the following location:
<http://www.aeronautics.nasa.gov/strategic-plan.htm>

The Plan lays out the vision for aeronautics research for the next 25 years and beyond, and includes a wide range of technologies that meet the future needs of the aviation community as a whole. The research plan is captured in a set of six strategic thrusts that guide ARMDs response to global trends. These six strategic thrusts are:

- Thrust 1: Safe, Efficient Growth in Global Operations;
- Thrust 2: Innovation in Commercial Supersonic Aircraft;
- Thrust 3: Ultra-Efficient Commercial Vehicles;
- Thrust 4: Transition to Low-Carbon Propulsion;
- Thrust 5: Real-Time System Wide Safety Assurance; and
- Thrust 6: Assured Autonomy for Aviation Transformation

QUESTION 3a:

What does NASA hope to accomplish in one, five, and ten years?

ANSWER 3a:

The research conducted by NASA Aeronautics is captured in 42 technical challenges that will be completed over the next 5 years. Some examples of expected accomplishments include data required for the development of standards for command and control communications as well as

sense and avoid performance and interoperability for unmanned aircraft integration into the national airspace system (2016), and various automation tools for air traffic management (2017-2020). Technical challenges for beyond the 5 year horizon will be formulated over the next 5 years that will align with our strategy and address the proposed research outcomes for 2025 identified in our Strategic Implementation Plan.

QUESTION 4:

Please explain how FAA and NASA coordinate to identify R&D gaps or duplication.

ANSWER 4:

There are two key ways that the FAA and NASA coordinate to identify R&D gaps or duplication. The first approach is at the strategic level. NASA's R&D scope is more focused at Technology Readiness Levels (TRLs) 1-4, whereas, the FAA is more focused at TRLs 7-9. That division of R&D focus and scope significantly reduces the likelihood of duplications. For R&D at the TRL's 4-7 phase NASA and the FAA typically form Research Technology Transfer Teams that provide close coordination and needed course corrections to enable feasible and efficient hand-offs. These teams help eliminate duplication and identify gaps early enough to enable appropriate courses of action to be taken.

The second approach relies on a series of planning documents, enterprise architecture roadmaps, embedded liaisons, and regular coordination meetings. The FAA publishes its research and development plan updates on an annual basis. The FAA also has a web-based enterprise architecture that provides details on implementation objectives and strategies. NASA participates in multiple planning & coordinating organizations: RTCA; Commercial Aviation Safety Team (CAST); Multiagency UAS Vision 2030 monthly partnership meetings, and others. NASA ARMD also has an FAA liaison at headquarters that supports the senior staff in providing strategic heads-up and high-level coordination between both agencies.

QUESTION 4a:

How do your agencies decide who will fund projects to address these gaps or who will move forward in the event of duplication?

ANSWER 4a:

Typically the TRL at which the gap or duplication occurs guides agency responsibility and investment. As technology matures to higher TRL, the RTT process ensures that applications are developed to levels sufficient for collaborative demonstration, and effective technology transitions and hand-off is prescribed at which point NASA investment stops and FAA carries the implementation forward.

QUESTION 5:

Please explain how NASA and FAA coordinate their aeronautics research with industry to ensure government research is not redundant or competing with the private sector?

ANSWER 5:

NASA and the FAA conduct and sponsor regular workshops and conferences with industry and academia involvement to communicate and share both intent and results of ongoing R&D activities for the entire community.

Specialized organizations and forums like the RTCA, CAST and the Aeronautics Research Technology Roundtable have industry participation and involvement precisely for the purpose to ensure that government research is not only not redundant nor competing with the private sector, but also to provide feedback that government research is positioned to best help the industry as a whole to move forward.

From a vehicle perspective, NASA coordinates closely with the FAA Office of Environment and Energy on vehicle-related research activities. For example, managers of the FAA Continuous Lower Energy, Emissions and Noise (CLEEN) research program and NASA vehicle projects meet routinely to ensure that research and development is coordinated and not duplicative. NASA employees serve as reviewers on proposed efforts under the FAA CLEEN program as well.

QUESTION 6:

How effectively are NASA-developed technologies being transitioned from research to implementation at FAA or by industry? Please provide specifics.

ANSWER 6:

NASA aeronautics has made decades of contributions to aviation through transfer of concepts and technologies to government and industry. NASA does not build aircraft, engines, or air traffic management systems. Through the research we conduct and research we sponsor with universities and industry, we help to develop the technology that enables continuous innovation in aviation. U.S. companies are well positioned to build on discoveries and knowledge resulting from NASA research, turning them into commercial products.

NASA aeronautics has made decades of contributions to the advancement of aviation technology. Every U.S. commercial and military aircraft flying today has technologies that are based on NASA research. An interactive overview of these contributions can be found at: http://www.nasa.gov/externalflash/aero_onboard/ A series of lithographs on NASA contributions can be found at: http://www.aeronautics.nasa.gov/onboard_lithos.htm

A recent technology that has been transferred and is being used on commercial aircraft such as the Boeing 787 and a number of other aircraft is the chevron nozzle, the serrated edges found at the back of jet engines. Chevron nozzles help to reduce the noise the jet engine produces by mixing the exhaust of the engine with free stream air. A web story on chevron

nozzles can be found at:

http://www.nasa.gov/topics/aeronautics/features/bridges_chevron_events.html

NASA Aeronautics developed technologies also are directly transferred to the Federal Aviation Administration (FAA). For example, over the last four years, NASA has transitioned to FAA five technologies for certification and integration into mid-term (2014-2018) NextGen operations. Most recently, NASA transferred the Terminal Sequencing and Spacing (TSS) suite to the FAA in July 2014 for further testing and evaluation, and subsequent near-term deployment through its enhanced terminal productivity program. TSS has received a full final investment decision from the FAA as part of its Time Based Flow Management (TBFM) program, which sets the stage for full-scale implementation across the National Airspace System. FAA intends to deploy the software tool throughout the NAS, including five major international airports located in Phoenix, Houston, Atlanta, Seattle and Los Angeles, before 2018. This software will help air traffic controllers manage airspace within a doughnut-shaped region of sky that begins five miles from a major airport and extends outward about 35 miles. The new technology will allow pilots to better use flight deck automation to fly fuel-efficient, optimized profile descents, which streamlines glide paths toward the runway reducing fuel use and noise toward an airport, and safely permits more flights to merge together at a point where they can be cleared for final approach and landing.

QUESTION 7:

How much does it cost NASA to support FAA programs?

ANSWER 7:

NASA works closely with the FAA and operational community to mature technologies for application in the near-term time frame supporting advanced automation for reducing delays, saving fuel, and enabling greater throughput and efficiency. Recent technology transfers to the FAA include automation to enable higher throughput arrivals in busy airports, smoother arrival flight paths for less fuel burn and noise, optimized airport surface movement reducing unnecessary stops and idling during taxi, and effective planning of take-off times to fit easily in available slots in the en route overhead streams. Delays are also reduced during the en route portion of a flight using NASA tools that examine weather impacts that could force large excursions to the planned route and proposing new flight paths that prevent the resulting delays saving fuel, crew time, and passenger time. Solutions for such weather delay avoidance are being developed as tools for use by airlines at their system operation centers for effective fleet management, as well as tools for flight crews to take advantage of highly accurate performance data for the specific aircraft to manage single flights for reduced delay and fuel savings. Collectively, as these capabilities are accepted and deployed by the FAA and operators over the next 5+ years, NASA developed technologies will provide greater access to safe, efficient, and cost effective air transportation.

NASA conducts research in advanced concepts and technologies for safe and efficient air traffic management systems that support both the current vision of NextGen as well as beyond NextGen concepts. Higher levels of automation as well as exploration of future autonomous approaches

are the subject of research and development. Also supportive of NextGen, NASA pursues vehicle-focused research and development, and advanced tools and technology for ultra-efficient commercial aircraft, innovative approaches for low-carbon propulsion concepts, and research to enable routine, high-speed transport operations. Additional research is conducted to integrate multiple technologies developed as part of the work above and demonstrate them in relevant environments; a specific example involves integration of unmanned aerial systems in the national airspace. Investment is also placed in the development of transformative aviation technologies that seeks to address the emerging needs of future NextGen states, and to develop the workforce of the future.

NASA's R&D scope is more focused at Technology Readiness Levels (TRLs) 1-4, whereas, the FAA is more focused at TRLs 7-9. That division of R&D focus and scope significantly reduces the likelihood of duplications. For R&D at the TRL's 4-7 phase NASA and the FAA typically form Research Technology Transfer Teams that provide close coordination and needed course corrections to enable feasible and efficient hand-offs. These teams help eliminate duplication and identify gaps early enough to enable appropriate courses of action to be taken.

The breakdown for ARMD funding for NextGen related activities is as follows:

\$millions

Program	FY 15 Enacted	FY 16 PBR
Airspace Operations and Safety Program	154.1	142.4
Advanced Air Vehicles Program	128.7	127.1
Integrated Aviation Systems Program	124.0	70.1
Transformative Aero Concepts Program	36.6	36.5
TOTAL NASA INVESTMENT	443.4	376.1

In FY 2014, NASA's contribution to NextGen programs totaled \$385M.

QUESTION 7a:

If NASA is doing work on behalf of FAA requirements, why shouldn't NASA be reimbursed by the FAA for that work so NASA can focus on cutting-edge research like hypersonic and supersonic research?

ANSWER 7a:

NASA performs cutting-edge research in our portfolio including concepts and technologies for aerospace operations. This is NASA's unique mission and responsibilities so it is appropriate that NASA gets funding from Congress for this cutting-edge research. As such, NASA typically is focused on those portions of the FAA requirements that still have high degrees of uncertainty or risk as to how to best meet the objectives safely and efficiently. This type of research often leverages NASA's unique facilities and labs to recreate the environments and to test out different specification and design philosophies.

QUESTION 8:

How much funding will NASA allocate to aviation-sector cybersecurity research in FY2016?

ANSWER 8:

At this time, NASA Aeronautics does not directly perform research and development on cyber physical systems security. However, we recognize that because of the nature of the resulting technologies we are working on related to autonomy in air traffic management and vehicle operations, there are strong implications for cyber physical security and its potential impacts. We are working closely with experts in the area of cyberphysical systems and security and other government agencies such as the DOD and NSF to account for these issues in research.

QUESTION 9:

To what extent were you, or anyone in your organization, consulted on the need or utility of aircraft emissions regulations ahead of the EPA's endangerment finding?

ANSWER 9:

NASA was not consulted on the need or utility of aircraft emissions regulations in this case. NASA does not generally play a direct role in setting emissions or other standards. Instead, NASA provides technical support and expertise to other federal agencies and international organizations to support development of standards and regulations. For example, NASA develops tools for systems analyses that are used by the FAA to help understand the potential benefits of advanced technologies. These are often integrated into FAA tools. In addition, advanced concepts studies (also conducted in coordination with industry) are useful for understanding potential future benefits. NASA is sometimes asked to provide insights based on technical expertise on what might be an appropriate metric for a standard, but NASA does not set specific levels. NASA subject matter experts have been asked to participate in some International Civil Aviation Organization (ICAO) Committee on Aviation Environmental Protection (CAEP) processes. However, NASA did not serve in this capacity for the recent CO2 standard work.

QUESTION 10:

Last year NASA fundamentally altered the structure of the Aeronautics Research Mission Directorate by moving from six program lines to four. Last year NASA also received nearly a \$100M increase for Aeronautics above FY 2014 levels. The FY 2016 budget request is \$80M below last year.

- a. Please explain the programmatic impacts of this budget request. For instance, are you planning to cut cutting-edge hypersonic, supersonic, or unmanned aircraft systems research? Are you planning to increase funding for "environmentally responsible aviation"?

ANSWER 10a:

ARMD moved from six program lines to four in order to better focus our research activities on priority technical challenges aligned with the six strategic research thrusts. ARMD's FY 2016 budget request supports a stable and balanced portfolio, with turnover in research activities expected as technical challenges are retired and new research activities begin. Although the Environmentally Responsible Aviation (ERA) project is ending in FY 2015 as scheduled, ARMD is continuing a strong investment in environmental-related technologies in the ARMD Advanced Air Transport Technology (AATT) and Revolutionary Vertical Lift Technology (RVLT) projects. ARMD also is planning to conduct high TRL ground and flight research on the most promising technologies from the ERA portfolio in the Advanced Air Vehicles Program and Integrated Aviation Systems Program.

ARMD used the additional funds in FY 2015 to accelerate new research emphases, improve ground and flight capabilities aligned with the strategy, fund strategic studies that support more robust and higher fidelity research and partnership planning, initiate strategic partnerships with universities and other research organizations that promote leadership and expand partnerships with the operational community to accelerate technology transition, and increase investments in convergent concepts and culture. These investments support our overall strategy and approach, while avoiding future year program "liens" or commitments.

Accordingly, there will be no "cuts" to hypersonics, supersonics or UAS research resulting from the \$80M reduction from FY 2015 to FY 2016. FY 2015 funding significantly advanced planning and research capabilities in these areas. NASA used FY 2015 funds in hypersonics planning and research to support development of a national plan, additional low-boom supersonic wind tunnel testing, and in the Live, Virtual, Constructive Distributed Environment (LVC-DE) build to improve the performance, connectivity and interfaces. The LVC-DE is the core capability required to flight test and validate key UAS operation standards, and to support additional UAS community partnerships.

QUESTION 10b:

Can you provide the Committee with a breakdown of the budgets for the programs, projects, and activities that comprise the four budget lines listed in the President's request?

ANSWER 10b:

The FY 2016 President's budget request for Aeronautics is attached.

QUESTION 11:

There has been some criticism that NASA's civilian supersonic R&D will only be useful for high-end business jets. If NASA and FAA would invest enough resources to develop supersonic flight over land in a safe and practical manner, how would that impact the aviation industry and all airline passengers?

ANSWER 11:

The primary challenge in supersonic overland flight is to establish a low sonic boom standard that would open a window of opportunities for commercial supersonic flight. NASA research on low boom aircraft shapes and development of physics-based aircraft design codes are indicating that generating such a low-boom signature is possible. It is expected that the initial application of commercial supersonics will be in smaller aircraft (business class). This class of aircraft has often been the pathfinder for advanced technologies (e.g. external vision systems), and the low-boom aircraft features will be easier to implement because of the small vehicle size. However, NASA wind tunnel testing has focused on smaller transport aircraft configurations due to the expectation that once the technology is proven, the market for larger vehicles will follow. NASA-stakeholder discussions indicate that while consideration of domestic passengers' ability to utilize supersonic flight is important, there is a more general economic benefit of producing and exporting such high-value products. For example, a supersonic business jet will be in great demand in other parts of the world (notably Asia and the Middle East) that can both afford such products and have a desire to travel great distances. U.S. industry has an opportunity to capitalize on our technological lead and exploit this capability and market opportunity for a positive balance of trade and job growth in the US. Ultimately, US industry and their projections of potential commercial markets (U.S. internal and export sales) will be the primary factor in the pace at which these capabilities are able to impact "all airline passengers."

QUESTION 12:

How much of NASA's aeronautics FY 2016 budget request is dedicated to hypersonic R&D?

ANSWER 12:

In the FY 2016 budget request, hypersonic R&D is \$15M.

QUESTION 13:

Is the U.S. losing its competitive advantage in hypersonic R&D to other countries, such as China?

ANSWER 13:

Specific discussions of foreign capabilities are sensitive and should not be part of an unclassified response.

QUESTION 14:

What is the value of NASA funding in FY 2015 related to environmental research, efficiency, alternative fuels, and other aviation-specific green initiatives?

ANSWER 14:

ARMD estimates \$323M of the FY 2015 budget is aligned with reducing the environmental impact of aviation. The estimate includes research into next generation aircraft configurations, efficient engines, and low carbon propulsion systems that enable dramatic reductions to fuel consumption, emissions, and noise. This estimate also includes development of a new integrated suite of air traffic management tools, which will expand airspace capacity with more fuel-efficient flight planning, diminish delays on the ground and in the sky, reduce fuel consumption, and reduce the overall environmental footprint of aviation.

QUESTION 15:

What are the R&D challenges facing UAS Traffic Management (UTM)? What is NASA doing to address these challenges?

ANSWER 15:

UTM is a new paradigm in transportation and mobility. This paradigm includes new vehicles, new missions, new pilots, new operators, new environments, and new policies to name just a few of the challenges. NASA is developing three strategic roadmaps to help organize and prioritize the top down R&D resources as well as coordinate the multidisciplinary efforts that will be required to address the challenges in UTM: Global Mobility; Real-time, System-wide Safety Assurance; and Assured Autonomy. NASA has adopted a rapid prototyping, spiral development approach collaborating with industry and aggressively funding NASA Research Announcements (NRA's) with industry to help accelerate both advanced modeling and design environments for this capability, but also targeted capabilities in command and control, trajectory management, self-separation methods, operator and pilot interfaces, system-wide monitoring and safety assurance and automation and autonomy enhancements to enable new missions and increase productivity. In addition, key research in human factors is helping to determine appropriate functional allocations between humans, systems, the appropriate degrees of autonomy, and decision-making methods. A rapid prototyping, spiral development approach will increase the rate and bandwidth of opportunities to test, adjust, and improve UTM architectures with the community to enable both a safe and efficient system to be deployed as soon as possible.

QUESTION 16:

How does U.S. R&D in the field of civil aeronautics compare to aeronautics R&D performed by foreign nations?

- a. How does the U.S. government's aeronautics R&D spending compare to government aeronautics R&D spending in the rest of the world?

ANSWER 16 & 16a:

Many governments around the world invest in aeronautics R&D, but comprehensive and consistent data on the level of spending by those governments is not presently

available due to differences in transparency of budgets and varying size, scope and method of funding provided. The twenty six members of the International Forum for Aviation Research (IFAR) represent the majority of the national governments with notable civil aeronautics R&D investment, although there are some additional national governments which also conduct R&D. National budgets often are also supplemented by state or regional government investments.

Collectively, European governments invest R&D funding through European-wide Framework programs (the Horizons 2020 program provides approximately \$4.9B in government-provided civil aviation funding from 2016 – 2020)¹ supplemented by individual EU member state government investments ranging from the tens of millions to hundreds of millions of dollars per year². Russia plans to invest \$6B in civil aeronautics R&D between 2013-2025³. Chinese civil aeronautics R&D budgets are not readily available, but reportedly over 20,000 employees are involved in the Chinese government aeronautics research enterprise⁴. Other non-European countries with notable government aeronautics R&D funding include Brazil, Canada, India, Japan, Korea, and South Africa.⁵

QUESTION 16b:

How does U.S. private sector aeronautics R&D spending compare to competitors abroad?

ANSWER 16b:

NASA does not have data on private sector civil aeronautics R&D funding levels.

QUESTION 17:

Because of FAA regulation, researchers at U.S. universities are not permitted to research UAS without a Section 333 exemption and a COA, while researchers at many foreign universities are not restricted from performing such research. Do you think our regulations on research will put the U.S. at a disadvantage in regards to UAS?

ANSWER 17:

¹ Clean Sky 2 has a budget of €4bn: <http://horizon2020projects.com/sc-transport/commission-readies-for-cs2-call/> SESAR has an overall budget of €1.5 billion, of which €500 million will be provided by the European Union and the rest by Eurocontrol and industry: http://ec.europa.eu/transport/newsletters/2014/07-11/articles/public-private-partnership_en.htm

² Figures provided directly to NASA by counterparts in those countries

³ Press release, Russian Central Aerohydrodynamic Institute, September 10 2014: http://tsagi.com/pressroom/news/1373/?print_course=Y&ELEMENT_ID=1373

⁴ Figures provided directly to NASA by Chinese Aeronautical Establishment (CAE).

⁵ Figures provided directly to NASA by counterparts in those countries

This question should be directed to the FAA. NASA has no basis to assess the impact of this FAA regulation.

QUESTION 18:

How does ARMD's research portfolio support the implementation of NextGen?

- a. What technologies are you working on? Are they FAA program requirements? If so, why isn't FAA funding them?

ANSWER 18 & 18a:

Please see answer to question #7.

QUESTION 19:

Since 2008, Congress has provided more than \$1.5B in developmental projects intended to explore new concepts and evaluate alternatives to reduce uncertainty and risks associated with NextGen programs. However, unlike major acquisition programs, these projects do not have formally approved cost and schedule milestones and do not receive the program oversight given to other procurement programs. In lieu of cost, schedule, and performance milestones, how does NASA ensure that these R&D programs are on budget and meeting their objectives?

ANSWER 19:

This question appears to relate to funding for the FAA.

Questions regarding appropriate oversight of FAA implementation of NextGen are appropriately directed to the FAA.

QUESTION 19a:

Without baseline cost, schedule, and performance metrics, how can Congress monitor progress on NextGen to ensure success?

ANSWER 19a:

NASA ensures that aeronautics research and development programs are on budget and meeting stated objectives through rigorous agency and Mission Directorate policies and processes. Specifically, ARMD measures its performance in accordance with the NASA Strategic-Performance framework (required by OMB-Circular A-11/GPRA Modernization Act of 2010), and also manages by Technical Challenges, which are funded activities with specific objectives that serve as the basis for planning research activities and additional performance measurement. All programs/projects are managed in accordance with NASA Procedural Requirement 7120.8, NASA Research and Technology Program and Project

Management Requirements, which establishes control systems, which ensure planning, execution, and performance to plan. Rigorous oversight of cost, schedule, and performance milestones of ARMD research is conducted through the Annual Project Reviews (with independent assessment), Annual Program Reviews, Quarterly Status Reviews, agency-level Strategic Objective Annual Reviews, and Baseline Performance Reviews. In addition, the NASA Advisory Council Aeronautics Committee advises the NASA Administrator through the NASA Advisory Council on strategic plans, programs, policies and other matters pertinent to the Agency's responsibilities for aeronautics research and development.

QUESTION 20:

An annual survey conducted by IT firm CSC and the Aerospace Industries Association found that only 50 percent of the aerospace and defense industry are investing in R&D. What steps do you take to ensure NASA is not crowding-out private sector investment?

ANSWER 20:

NASA Aeronautics solely invests in precompetitive research and technology development that is beyond the horizon of most private R&D work. The return on investment for low technology readiness level research is much further in the future than is typically required by private sector companies responsive to their shareholders, and the resulting advances typically benefit the broad community, making investment in such research by individual companies less attractive. As the technology readiness level of research results increases, we look to partnership with industry for cost sharing opportunities. We make these efforts to encourage industry investment in research and development.

QUESTION 21:

UAS command and control technologies are vital to ensuring safe operation of UAS in the NAS. What is the current state of R&D on UAS command and control? What more needs to be done?

ANSWER 21:

NASA, other government agencies and industry are partnering to address key research questions associated with secure command and control for safely operating UAS in the NAS including the following.

What frequency spectrum is appropriate for UAS? How do we develop and test a communication system? What are the security vulnerabilities that might exist in a communication system? What frequency spectrum is appropriate for UAS communications?

The UAS Communication work with NASA's UAS Integration in the NAS Project addresses safety aspects of UAS communications when operating in the NAS.

- NASA in conjunction with an industry partner is testing a prototype control communication radio system to allow the validation of proposed UAS communication system requirements in a relevant environment, utilizing frequency bands identified for UAS operations.
- NASA is working in partnership with the FAA and the National Institute for Standards and Technology (NIST) to analyze and develop mitigations to potential security vulnerabilities of the UAS control communication system.
- NASA is conducting large-scale simulations of the UAS communication systems considering a NAS-wide deployment of UAS.
- The Project is working with the International community to identify spectrum bands to enable safe control of UAS. NASA assisted the community to identify spectrum for line-of-sight (terrestrial) UAS communications and the consider spectrum for beyond line-of-sight (satellite) for UAS communications.

The current state of the art research is addressing terrestrial communication systems. For routine integration of UAS into the NAS a safe, robust, secure satellite communication system will have to be validated. Plans are underway to address the standards associated with satellite communications for UAS as part of Phase II of RTCA's SC228 work.

QUESTION 22:

Does anything prevent NASA from hosting private sector UAS testing?

ANSWER 22:

Within the authority granted NASA through the Space Act of 1958, NASA can partner with private sector entities to conduct research associated with UAS integration into the NAS.

**HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
SUBCOMMITTEE ON SPACE**

“Transforming America’s Air Travel”

Dr. Jaiwon Shin, Associate Administrator, Aeronautics Research Mission Directorate, NASA;
Member, FAA Research and Development Advisory Committee

Questions submitted by Rep. Donna Edwards, Ranking Member, Space Subcommittee

QUESTION 1:

The traveling public is probably not aware that many of the features in jetliners they fly on are directly linked to innovations that came out of NASA's aeronautics research program. Many of NASA's innovations are enabling incremental improvements that are reducing fuel consumption and enhancing safety. Does NASA's focus on future aircraft designs, such as the blended wing, mean that we have exhausted the ability to realize additional gains from current aircraft designs?

ANSWER 1:

The aviation industry has not yet exhausted the ability to realize additional gains from current tube-and-wing aircraft designs however, in many cases the technologies that are available for tube-and-wing design improvements may be at higher maturity levels for which industry is best suited to advance them. NASA's role in research is to undertake R&D efforts that are outside the scale, risk, and payback criteria that govern commercial investments, with the purpose of proactively transitioning the research findings to the aviation community. In this case, the advanced configurations (such as the blended wing or others) are considered high risk but with potentially very high payoff in terms of efficiency and performance improvement. By collaborating with industry on appropriate tube-and-wing related technologies and by leading the investigation of novel future designs, NASA maintains a balanced portfolio to contribute to the near-, mid-, and far-term. Additionally, by investigating these novel future designs, state-of-the-art technical discipline capabilities in (such as aerodynamics and computational prediction of physical phenomena/design performance) are stretched to advance well beyond current capabilities. These advancements, spurred by the study of novel future designs, feed back into industry design tools and codes to benefit more near-term configuration designs. It should also be noted that many of the long-term technologies that NASA is currently working are also applicable to advanced tube and wing configurations.

QUESTION 2:

How is your Directorate addressing the issue of its aging internal workforce and the Possibility of the loss of unique competencies in the near future?

ANSWER 2:

Maintaining a highly competent workforce and capturing and transitioning knowledge from retiring employees to existing and new staff are important priorities for ARMD. We have instated informal mentorships to pass on experiences to new employees, such as forming research teams consisting of experienced and newer employees to facilitate the hands-on transition of experience and knowledge to new employees. ARMD also actively encourages staff to participate in NASA career development programs and rotational assignments to headquarters and the centers to expand the experiences of employees. In some cases, ARMD is able to retain and transfer knowledge through the retention of retired employees as subject matter experts through contracts providing opportunities to pass on their years of experience to current employees and in some cases their successors. ARMD uses the NASA Scientific and Technical Information (STI) publication program as well as outside publications including technical papers and journal articles to ensure the results of our research are documented for others.

QUESTION 3:

A key barrier to supersonic air travel is addressing the noise and impact of the sonic boom, and I understand that NASA is carrying out research to develop design capabilities that will lower the sonic boom. What level of sonic boom is required to enable overland supersonic air travel? How is NASA's research informing FAA's regulations on sonic boom?

ANSWER 3:

NASA research on reduced noise sonic boom has indicated that a level of 70-75 PLdB (Perceived Level decibels/dB*) will result in little or no annoyance whether heard indoors or outdoors. This level has been determined based on laboratory studies and simulated low booms from special flight trajectories flown by NASA research aircraft. Final confirmation of the acceptable noise level will require over-flight testing of a statistically relevant sized set of communities that are not currently exposed to sonic booms. This testing would require a specially designed research aircraft with the desired boom noise characteristics and would collect both human and building structural response data. NASA and the FAA are working in a coordinated manner on research needed to consider changing current rules prohibiting supersonic overland flight. Results of NASA's on-going research in approaches to reducing sonic boom noise are actively shared with the FAA. Additionally, NASA supports the FAA's role as a member of the International Civil Aviation Organization's (ICAO) Committee on Aviation Environmental Protection (CAEP) Noise Working Group. NASA sonic boom response research from laboratory and flight simulations is being used by FAA and CAEP in the early development of metrics and procedures for a future supersonic overland noise certification scheme.

* Perceived Level is a noise response measure similar to the more common dBA, but more suited to impulsive noise such as sonic boom.

Responses by Mr. Dennis Filler

**HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
SUBCOMMITTEE ON SPACE**

“Transforming America’s Air Travel”

Mr. Dennis Filler, Director, William J. Hughes Technical Center, FAA

Questions submitted by Rep. Brian Babin, Chairman, Space Subcommittee

QUESTION #1: Are the decisions of the FAA Research and Development Executive Board (REB) subject to an annual external review process?

- a) If so, please describe any and all external reviews of FAA R&D activities, including the annual R&D goals, objectives, targets, and methods of evaluation of the REB.
- b) What value would or does an annual external review of FAA’s R&D goals, objectives, targets, and methods of evaluation bring to the FAA?

RESPONSE:

- a) The FAA Research and Development Executive Board (REB) is the governance body responsible for review and approval of the FAA R&D portfolio as part of the annual budget formulation process. Its primary responsibility is to coordinate the annual R&D investment portfolio across all four appropriations. The REB’s review and approval of the FAA R&D investment portfolio is augmented by various external reviews. Principal among these is the review conducted by the Research, Engineering and Development Advisory Committee (REDAC) whose membership includes representatives from industry, academia, and government. The REDAC provides advice and recommendations to the FAA Administrator on the needs, objectives, plans, approaches, content, and accomplishments of the aviation research portfolio. The portfolio also undergoes detailed independent review by the Office of Management and Budget (OMB) to ensure alignment with the administration’s goals and priorities. Periodically, the FAA also seeks feedback on particular topics relevant to research program execution from the National Academies of Science.
- b) The FAA welcomes and derives considerable value from the independent external reviews cited above. In particular, the R&D program findings and recommendations provided by the REDAC are carefully considered by the performing organizations and REB representatives. To the extent that these recommendations are actionable they are pursued, reported on, and tracked through closure by the responsible FAA offices.

QUESTION #2: The FAA is required by law to provide Congress with the National Aviation Research Plan (NARP) annually with the President's budget request.

- a) Why has FAA failed to deliver the NARP for FY14, FY15, and FY16?
- b) It was reported in your testimony that the FAA has sent these documents to the White House for review. Please explain why the White House has yet to complete its review for the FY14, FY15, and FY16 NARPs individually.

What action does FAA take to ensure the White House completes its review of the NARPs by the statutory deadline in 49 U.S.C. § 44501(c)?

RESPONSE:

- a) Due to the uncertainty that surrounded the FY 2015 budget, preparation of the accompanying National Aviation Research Plan (NARP) (i.e., the FY 2014 document) was delayed and subjected to longer than usual review. Although the FY 2014 NARP was completed and coordinated with all relevant agency business units, the extended review resulted in considerable overlap in the coordination of the FY 2014 and FY 2015 documents. To preempt the potential confusion and difficulty that could result from near-concurrent coordination and transmittal of both documents, the FAA decided to withhold transmittal of the FY 2014 NARP until the FY 2015 document was completed; at that point both would be transmitted concurrently with an explanatory note. Both documents are now completed and pending clearance for final transmittal. The FY 2016 NARP is not yet due; it is to be transmitted concurrent with the presentation of the FY 2017 budget.
- b) At the time of the hearing the FY 2014 and FY 2015 NARP had completed internal FAA coordination and were transmitted for final clearance. We also had pre-coordinated and obtained concurrence with both documents. The FAA presently is coordinating development of the FY 2016 NARP with all relevant FAA offices. Drawing upon the lessons of the FY 2014/2015 development cycles, we intend to pursue early coordination of preliminary drafts with all external reviewers to ensure prompt final clearance and transmittal in accordance with the statutory deadline.

QUESTION #3: What R&D activities is the FAA undertaking to examine the feasibility, benefits, challenges, and opportunities associated with the privatization of the National Air Traffic Control System?

- a) Has the FAA sought technical guidance from other countries that have privatized as to the feasibility, benefits, challenges, and opportunities associated with the privatization of the National Air Traffic Control System?

RESPONSE:

The FAA commissioned MITRE to study the impact on foreign Civil Aviation Authorities (CAAs) of privatizing ATC systems. The study¹ included a comparison of governance, autonomy, structure, and funding of CAAs of the UK, Canada, France, Germany, Australia, and New Zealand and provides lessons learned in separating the CAA from the air navigation service provider (ANSP).

In addition, the FAA routinely interacts with other countries with differing ANSPs or Air Traffic Control organizations through its support of the International Civil Aviation Organization (ICAO) and as a member of the Civil Air Navigation Services Organization (CANSO). Our work with these and other organizations requires knowledge and understanding of foreign authorities' air traffic and aviation safety governance and funding structures, as well as the efficiency, safety, and modernization performance of foreign aviation systems under different structures.

Aside from the above referenced MITRE study, no specific study or specific technical guidance has been sought directly from other countries, with respect to the proposal being discussed by Congress.

QUESTION #4: What is FAA's plan for future research and development?

- a) What R&D does FAA hope to accomplish in one, five, and ten years?
- b) What does FAA hope to focus its research on after NextGen is fully implemented?

RESPONSE:

- a) Anchored by the three underlying R&D principles—(1) Improve Aviation Safety; (2) Improve Efficiency; (3) Reduce Environmental Impacts—and 21 subordinate goal areas, the FAA continually assesses emerging needs of the aviation community and prioritizes initiatives within its research portfolio to address those needs. The NARP serves as the FAA's 1-to-5 year research planning document and expresses the outcomes to be achieved in that timeframe. The latest NARP specifies more than 300 research milestones to be achieved across 32 program areas between 2016 and 2021.

To establish long range R&D thrusts in the 10+ year timeframe, the FAA requested the Research, Engineering and Development Advisory Committee (REDAC) to leverage their collective expertise and knowledge of the industry to provide FAA with advice to enable development of an R&D portfolio that is strategic, responsive, and addresses future R&D needs of the FAA. The REDAC and its constituent

¹ MITRE, CAA International Structures, October 2014. <http://www.mitre.org/publications/technical-papers/caa-international-structures>

subcommittees responded to that request with a set of recommended long term research areas that represent emerging issues or research opportunities that the FAA should get ahead of. The FAA concurred with the REDAC's input and expects to place considerable research emphasis in the following six areas in the 10 year time-frame:

- Integration of UAS in the NAS
 - Validation and Verification of Increasingly Complex NAS systems
 - Human Factors of Increasingly Automated Systems
 - Data Integrity and Cyber-Security
 - Challenges and Opportunities of Big Data in the NAS
 - General Aviation Safety
- b) Our aviation system will continue to evolve over time to address continued improvements in safety, efficiency and environmental sustainability. There also will be changes in technology that will require changes to the NAS. While we cannot estimate precisely the extent of these changes, we expect that our research program initiatives will continue to be governed by the same three foundational R&D principles. At this point in time we anticipate increased research efforts across the emergent areas identified by the REDAC which are listed above.

QUESTION #5: The FAA Modernization and Reform Act directed the FAA to develop a research plan for the certification of new technologies into the National Airspace Systems (NAS) and to have the National Research Council (NRC) review that plan.

- a) Please explain why the FAA failed, in the words of the NRC, "to meet the requirements of the authorizing legislation" and develop a plan that "lacks detail and specificity and does not provide an effective guide to FAA research over the 5-year term required" by the Act?
- b) What will the FAA do to address this deficiency and implement the recommendations of the NRC?
- c) What would be the characteristics of a well-designed Certification Research Plan?
- d) Could you create such a plan with the resources currently allocated to FAA R,E&D?

RESPONSE:

- a) Congress asked the FAA to prepare a research plan on a narrowly focused topic, and asked that the NRC review that special topic research plan. The FAA has a much more comprehensive, performance-based National Aviation Research Plan (NARP) that ensures all research and development that the agency conducts – including NextGen – is well managed, delivers results, and fulfills national aviation priorities. That overall research plan is much broader in scope than the narrowly-focused plan the NRC reviewed, and addresses the near-, mid-, and far-term research needs of the

aviation community. It details R&D principles and goals that support the strategic national aviation vision.

- b) A number of measures complement the plan, including, but not limited to, research and development plans specific to individual projects, an Acquisition Management System process that oversees FAA capital investments, and certification requirements that ensure all avionics equipment used in the National Airspace System (NAS) meet stringent federal standards.

Certifying new technologies in our airspace must be done with safety as our leading concern. We have rigid processes and multiple layers of testing and evaluation to ensure confidence before we introduce new features in our air transportation system. New technologies can't be accelerated unilaterally. Rather, we work with the aviation community on potential solutions and requirements needed to make new components work for multiple users and to operationally integrate it.

We are working to more quickly respond to changes in the marketplace without compromising safety. For example, we have in recent years worked with our research partners, such as NASA, to improve the path to implementation by incorporating requirements and safety assessments at the beginning of the evaluation process.

- c) A well designed research plan should benchmark the best practices of other organizations regarding certification that can contribute to the timely implementation of NextGen technologies and coordinate its research with other relevant organizations, particularly NASA.

The FAA plan includes outreach beyond the FAA to gather lessons learned and best practices. The research plan's lack of direct acknowledgment of sources such as NASA is not an indication of a lack of engagement. We have very strong engagement with NASA as part of our Research Transition Teams, which cover topics related to this proposed research.

- d) The FAA determined that a 5-year research budget of \$4.6 million is required to execute the plan. This research plan is not currently included or funded in the NARP, partially because it needed to go through an independent review and adjudication process with the National Research Council.

QUESTION #6: Please explain how NASA and FAA coordinate their aeronautics research with industry to ensure government research is not redundant or competing with the private sector?

RESPONSE:

FAA and NASA utilize a number of mechanisms to collaborate and coordinate aeronautics research. This includes participation on numerous planning, advisory, and coordinating bodies. In particular, NASA participates on FAA's Research, Engineering, & Development Advisory Committee (REDAC), which is responsible for coordinating the FAA's aeronautics research with industry and other government agencies. NASA is also a key participant in the FAA's Interagency Planning Office (IPO), whose mission is to identify and prioritize research, and successfully integrate individual agency programs and activities. The FAA's IPO has participation from both NASA and industry through the NextGen Institute. The NextGen Institute provides a mechanism to allow the private sector to actively engage with government to foster agreement on priorities, harmonize research and implementation activities, and create the public/private cooperation needed to transform the air transportation system.

QUESTION #7: How do current and proposed FAA R,E&D programs address airliners being compromised?

a) How do they address national air traffic control hacks?

RESPONSE:

Since 2005 the FAA has been using research and applying special conditions and companion issue papers to address electronic cybersecurity threats to aircraft systems and networks. The FAA's Transport Airplane Directorate has issued over twenty special conditions for certain make and model airplanes since that time, working closely with manufacturers to ensure the security of aircraft operating systems on e-enabled aircraft. That work began with the certification program of the Boeing 787 Dreamliner, where the FAA sponsored research on aircraft systems information security protection with the Volpe Center, which included input into the development of special conditions and companion issue papers.

New Part 25 aircraft as well as any legacy Part 25 aircraft involving change to network connectivity require a security risk analysis and, if required, the application of the special conditions and companion issue papers.

From the aircraft systems information security protection (ASISP) standpoint, for which the FAA's Aircraft Certification Service is responsible, the FAA is currently addressing cybersecurity through one comprehensive R&D requirement that addresses aircraft systems information security – A11D.SDS.1: Onboard Network Security and Integrity (Aircraft Systems Information Security Protection). Tasking is developed to identify apertures into

aircraft avionics systems, identify vulnerabilities, perform risk analysis, identify mitigations, etc. The request for FY16 funding is \$1.5 million and the planned funding for FY17 is \$1.575million.

The FAA has sponsored various research activities on ASISP including a recent publication on “Potential Cybersecurity Issues for the ARINC 429 Avionics Data Bus and Line Replaceable Units (LRUs)” by the FAA’s William J. Hughes Technical Center. The FAA is also sponsoring research for MIT to develop recommendations and best practices for field loadable software (FLS) for airborne aircraft systems.

Collective research efforts with the Technical Center, original equipment manufacturers (e.g., Boeing, Honeywell), the Air Force, suppliers, operators, and maintainers are taking place. This includes, for example, research on security controls on field loadable software, electronic flight bags, portable electronic devices, and similar devices.

- a) The FAA addresses attempted cyber-attacks on the National Airspace System (NAS) through a combination of protection, detection, and response capabilities and processes. The NAS is a fully privatized networking infrastructure that is protected at its boundaries by security gateways used to control and monitor all data traffic to and from external entities. Within the private NAS infrastructure systems are hardened using security standards, data communications are controlled via access lists, and security events are centrally monitored for malicious behavior by NAS Cyber Operations (NCO). When potential malicious behavior is detected within the NAS, the NCO leads response efforts to provide situational awareness to all stakeholders, develop response courses of action, and implement remediation and recovery actions to minimize the impact on NAS availability and integrity. Reporting of NAS cybersecurity incidents is performed by the NCO through the Department of Transportation (DOT) to US-CERT in accordance with Federal Incident Notification Guidelines.

QUESTION #8: How do FAA and NASA coordinate with the DoD and other national security agencies on civil aeronautics-based cybersecurity R&D?

RESPONSE:

Working through the Interagency Planning Office (IPO) for NextGen, the FAA established the Interagency Core Cybersecurity Team (ICCT) in May of 2015. The ICCT is a multiagency cyber team co-chaired by FAA, DoD, and DHS and hosted by the IPO. It is comprised of members from the NextGen partner agencies to promote consistent coordination on cybersecurity matters. It provides a means to address aviation cybersecurity issues relevant to NextGen and to interagency information sharing; to leverage research and development capabilities from multiple federal agencies to facilitate multiagency aviation cyber exercises and R&D planning; to discuss and formulate NextGen cybersecurity direction; and to develop multiagency recommendations for cyber R&D, policy, strategy,

governance, best practices, and requirements. Additionally, the ICCT enjoys cross-domain membership with the Aviation Information Sharing Analysis Center (A-ISAC) which leverages the private sector with links to government subject matter experts. The A-ISAC is able to analyze and share timely, relevant, actionable cyber-related information to protect aviation business, operations and services.

QUESTION #9: How much funding will FAA allocate to aviation-sector cybersecurity research in FY16?

RESPONSE:

The FAA investments on cybersecurity research includes investments in efforts targeted at regulatory aspects of digital system safety and MITRE CAASD work supporting cybersecurity aspects of NAS infrastructure. They total \$1.5 million and 4.5 MITRE staff years (approximately \$1.3 million) in FY 2016.

QUESTION #10: To what extent were you, or anyone in your organization, consulted on the need or utility of aircraft emissions regulations ahead of the EPA's endangerment finding?

RESPONSE:

Over the last seven years the FAA has been working within the International Civil Aviation Organization's (ICAO) Committee on Aviation Environmental Protection (CAEP) to develop an aircraft carbon dioxide emission standard. Representatives from the aircraft manufacturing industry, airline operators, EPA, and environmental non-government organizations have been participating as well. During that time the FAA and EPA have discussed the technical aspects of the standard development and coordinated on some of the inputs to the CAEP working groups charged with developing the standard. Prior to EPA's recent Federal Register notice concerning its proposed endangerment finding and Advanced Notice of Proposed Rulemaking (ANPRM) for aircraft emissions regulations, there were extensive consultations between OMB, EPA and FAA. These discussions were primarily intended to ensure that the work of the ICAO CAEP was accurately conveyed as setting the potential basis for future rulemaking by EPA in response to its proposed endangerment finding.

QUESTION #11: The FAA FY 16 President's Budget Request includes \$198 million for research and development funding under the Facilities and Equipment (F&E) account and \$46 million under the Grants-In-Aid for Airports (AIP). Please detail what programs, projects or activities are included in these requests related to R,E&D?

RESPONSE:

The F&E request is comprised of the following budget line items. Specific programs and projects are described in the budget narratives. These programs fall within the category of development (defined as systematic application of knowledge or understanding, directed toward the production of useful materials, devices, and systems or methods, including design, development and improvements of prototyping and new process to meet specific requirements). OMB Circular A-11.

Facilities & Equipment**Advanced Technology Development & Prototyping**

1A01 - Advanced Technology Development & Prototyping – \$21,300,000

FAA Advanced Technology Development & Prototyping program develops and validates technology and systems that support air traffic services. These initiatives support the requirements associated with evolving air traffic system architecture and improvements in airport safety and capacity.

Plant – Support of the physical facilities and equipment located at the William J Hughes Technical Center

1A02 – NAS Improvement of System Support Laboratory -\$1,000,000

1A03 – William J. Hughes Technical Center Facilities - \$19,050,000

1A04 – William J. Hughes Technical Center Infrastructure Sustainment - \$12,200,000

Center for Advanced Aviation System Development (CAASD) – CAASD is the FAA’s Federally Funded Research and Development Center that supports the development of policy and investment decisions for the NAS Systems and NAS Enterprise Architecture.

4A01 – Center for Advanced Aviation System Development - \$60,000,000

NextGen Applied Research and Development

1A05 - NextGen – Separation Management Portfolio - \$26,500,000

Separation Management Portfolio encompasses activities to provide controllers with tools to manage aircraft tactically for separation and merging in a mixed environment of varying aircraft navigation equipment and wake performance capabilities.

1A06 - NextGen – Improved Surface/TFDM Portfolio - \$17,000,000

Improved Surface/Terminal Flight Data Manager improves airport surveillance information and automation to support airport configuration management, runway assignments and surface traffic management, and to support enhanced cockpit displays to provide increased situational awareness for controllers and pilots.

1A07 - NextGen – On Demand NAS Portfolio - \$11,000,000

On Demand NAS portfolio provides flight planners, Air Navigation Service Providers staff, and flight crews with consistent, complete, and easily processed information on changes of conditions in the NAS affecting safety, security and efficiency for individual flights.

1A08 - NextGen – Environmental Portfolio - \$1,000,000

Environmental Portfolio will utilize an Environmental Management System framework to track environmental performance of the national air space and examine mitigation solutions to reduce the impacts of aviation on the environment.

1A09 - NextGen – Improve Multiple Runway Operations Portfolio - \$8,000,000

Improve Multiple Runway Operations Portfolio improves runway access through the use of improved technology, updated standards, safety analysis, and modifications to air traffic monitoring tools and operations procedures that will enable more arrival and departure operations.

1A10 - NextGen- NAS Infrastructure Portfolio - \$11,000,000

NAS Infrastructure Portfolio provides cross-cutting development and analysis of capabilities that have substantial cross-portfolio dependencies and/or legacy NAS Infrastructure cost effective improvements.

1A11 - NextGen – Laboratory Support Portfolio - \$10,000,000

The Laboratory Support Portfolio focusses on evaluating future concepts and technology to support a tech transfer to implementing organizations, promote industry involvement, and to identify implementation challenges and research areas.

Grant in Aid for Airports (AIP)

Airport Technology Research - \$31,000,000

The Airport Technology Research program supports airport specific FAA research in the areas of airport safety, airport state of good repair, and environmental sustainability.

Airport Cooperative Research - \$15,000,000

The Airport Cooperative Research program supports airport specific research recommended by the Transportation Research Board of the National Academy of Science to support the goals of safety, economic competitiveness, and environmental sustainability.

QUESTION #12: What are the R&D challenges facing UAS Traffic Management (UTM)? What is the FAA doing to address these challenges?

RESPONSE:

In October 2014, FAA and NASA jointly formed another in a series of Research Transition Teams (RTTs) focused on NASA's UTM concept. One of the FAA's responsibilities in the RTTs is to provide operational service unit personnel that can identify the operational need as well as the barriers to implementation.

Over the past year, the UTM initiative has evolved beyond NASA's traditional research. As a result, FAA will not only be providing operational subject matter expertise, but will also take on a leadership role working collaboratively with NASA in the maturation of the UTM concept because of the policy, regulatory, airspace and infrastructure implications FAA is responsible for addressing as the Air Navigation Service Provider (ANSP).

No one can predict specific outcomes of the UTM research initiative at this early stage, but we are encouraging research into how unmanned aircraft, in low-altitude airspace, can be managed safely and efficiently. Both DoD and DHS have agreed to provide subject matter experts as well within the RTT. They will be of great value to NASA, FAA and the UAS community as we sort through options and solutions.

QUESTION #13: The FAA won't allow full integration of UAS into the NAS until technologies like detect-and-avoid are fully developed. How does the R,E&D component of FAA work with the UAS Integration Office to determine which technologies FAA should research, and when they should research them?

- a) How will the recently announced UAS senior adviser position interact with R,E&D?
- b) How does R,E&D currently play a role in validating new UAS technologies to inform UAS regulations?

RESPONSE:

The FAA's NextGen organization works with our external partners (e.g., DoD, NASA, DHS, test sites, etc.) to leverage UAS research in support of common needs and goals. This research includes work to support RTCA and other standards organizations in their efforts to

develop and validate standards for detect-and-avoid, command and control, and other technologies needed for UAS to fly safely and efficiently in the NAS.

- a) The UAS senior advisor position will help the UAS integration office gain perspective on the many and varied research interests of our government and industry partners so that their research can be leveraged to support UAS NAS integration needs and research can be designed or revised for research needs that are not fully addressed.
- b) UAS research supports standards development and the validation of draft standards by providing a technical basis for the safety and efficiency requirements the UAS technologies are designed to address. The resulting technologies inform UAS regulations by providing a means to comply with existing regulations, justify the safety of a waiver or exemption to existing regulations, or provide the technical basis for a new or revised regulation.

QUESTION #14: Does FAA use the UAS test sites for R&D? Why or why not?

- a) If so, how often does FAA use the test sites?
- b) How much of FAA's budget will go to UAS test sites, either to support operations or conduct research?
- c) What could be done to make the test sites more attractive for use by government partners?

RESPONSE:

a) The six UAS test sites have established their research agendas. The William J. Hughes Technical Center is currently receiving operational data from test sites that will help answer key questions about how unmanned aircraft interface with air traffic control. The Technical Center will work closely with the test sites to identify the data most useful to the FAA.

To collect this operational data from the test sites, the FAA developed the prototype Certificate of Airworthiness Mission Logging System to capture all COA online data. The system is designed to easily expand to accommodate additional research data collection areas as they are identified. As of May 2015, all six test sites were granted access to the prototype system. The FAA developed prototype Mission Logging System was designed to capture UAS operational information inclusive of incident and accident data from the six UAS test sites.

As a result of the broad scope of test site research activities beyond test site COA flight operations, the FAA updated the Mission Logging System to capture all research activities

including non-flight related research occurring at the test sites. The Mission Logging System was also upgraded so the test sites could enter their quarterly reports directly into the system based on the research areas they identified as having reported against. In addition to narratives against specific research areas, the test sites can upload and store research as part of the quarterly submission process. This high-level narrative enables the FAA to match test site activities with complimentary research efforts being conducted by the FAA.

The FAA UAS Center of Excellence (CoE) also has two test sites as team members. There is an expectation that the CoE will use these test sites to conduct research flight operations and collect research data.

Beyond the value of monthly flight operation statistics, the research conducted at the UAS test sites will be available online for FAA review to identify those research projects which complement and/or further research areas identified by the FAA. This will facilitate collaborative analysis of research data with the end goal of safe integration of UAS into the NAS.

- b) Currently, the FAA does not fund research at the UAS test sites directly. However, the FAA, in addition to the information provided by the test sites on research including flight operations, has executed Master Agreements with each of the test sites in July 2015 that will enable the FAA to fund UAS research at one or more of the test sites.
- c) Research directed to the test sites similar to the NASA solicitation may have the effect of attracting similar activities from government agencies.

On June 4th, 2015, NASA released a solicitation with the intent to award one or more contracts to UAS test sites. Two NASA projects are identified (UAS Traffic Management and UAS Integration in the NAS).

Although documentation of research activities conducted by the test sites with government agencies is not available, during meetings with the test sites many, if not all, of the test sites made references to UAS research relationships with different government agencies.

QUESTION #15: How does the Test Center work with FAA to advance UAS regulations?

RESPONSE:

The William J. Hughes Technical Center serves as the FAA's technical base for research and development, test and evaluation, and verification and validation in air traffic control, communications, navigation, airports, aircraft safety, and security. The Technical Center is the nation's premier air transportation system laboratory for the FAA's full spectrum of

aviation systems. The Technical Center develops scientific and technical solutions to current and future air transportation challenges such as UAS integration by conducting research and development in collaboration with industry, academia, and government. The research and technical solutions provided by the Technical Center gives the FAA the information needed to assist in the development of UAS rules, policies, and regulations.

The Technical Center's UAS research efforts include:

- Determining certification criteria associated with operational and airworthiness approval for UAS sense-and-avoid systems.
- Recommending safety thresholds for UAS characteristics such as kinetic energy, structure, shape, or other safety features.
- Evaluating surveillance sensor fusion strategies which support autonomous detection and avoidance of other aircraft.
- Evaluating the impact to air traffic controllers' work load in scenarios where UAS entered contingency modes of operation such as lost communications or lost control link.
- Human in the Loop testing to support UAS procedures and operations.
- Collection and analysis of UAS safety data from UAS test sites.

QUESTION #16: How does the Test Center use the Small UAS Horizons initiative to work with industry partners on R&D efforts?

RESPONSE:

The Small UAS Horizons initiative (Pathfinder) was announced on May 6, 2015 to explore the next steps in unmanned aircraft operations beyond the type of operations the agency proposed in the small unmanned aircraft systems (UAS) notice of proposed rulemaking published in February. The FAA is working with industry partners on three focus areas, including:

- Visual line-of-sight operations in urban areas: CNN will look at how UAS might be safely used for newsgathering in populated areas.
- Extended visual line-of-sight operations in rural areas: This concept involves UAS flights outside the pilot's direct vision. UAS manufacturer PrecisionHawk will explore how this might allow greater UAS use for crop monitoring in precision agriculture operations.
- Beyond visual line-of-sight in rural/isolated areas: BNSF Railroad will explore command-and-control challenges of using UAS to inspect rail system infrastructure.

This project is currently in the discovery phase and is investigating research needs and requirements. Consequently, there is not a requirement for the project to utilize research performers at the William J. Hughes Technical Center, FAA's UAS Center of Excellence, or

in industry. Those options are being explored and as the project matures, collaborative research efforts will be conducted.

QUESTION #17: According to GAO testimony provided on March 24th, 2015, to the Senate Subcommittee on Aviation, Operations, Safety, and Security, there is uncertainty about what research and development should be conducted at FAA UAS Test sites to support UAS integration. What is the FAA doing to address this? Please provide specifics.

RESPONSE:

The FAA has and continues to provide UAS test sites with recommendations for research areas. In May 2014, the FAA provided the test sites with "Integration of Unmanned Aircraft Systems into the National Airspace System: Concept Level Requirements for UAS Test Sites and Other Researchers Version 1.0" which contained all the research areas that the FAA identified as required for UAS integration into the NAS.

Further in September 2014, at the 2nd Technical Interchange Meeting, FAA gave a presentation on "Potential Research Areas to the Test sites". In October 2014, FAA provided the document, which contains 7 broad categories that totaled over 120 potential research areas with over 50 specifically identified as research suitable for the test sites. Research identified includes the areas of: certification (including sense and avoid, maintenance, security, environmental, communications and airworthiness), flight planning, operational approvals, operations and safety. The test sites have been informed that these research areas are not static and will evolve as UAS integration matures to support operational scenarios and policy issues.

Additionally, the FAA has met one-on-one with several of the UAS test sites to discuss their proposals for research activities. These discussions include, but are not limited to, feasibility of the research, next steps and FAA participation.

QUESTION #18: According to GAO testimony provided December 10th, 2014, to the House Transportation and Infrastructure's Subcommittee on Aviation, test site operators told GAO that the sites are "significantly underutilized" by the FAA and the private sector. What steps is the FAA taking to provide additional flexibility to test sites to encourage greater use by industry?

RESPONSE:

In May 2015, FAA granted, with certain conditions, the UAS test sites a broad Certificate of Waiver or Authorization for Public Aircraft Operations at or below 200' Above Ground Level

across the entire United States. This blanket authorization offers a new opportunity to the UAS test sites.

QUESTION #19: When looking at the fiscal year 2016 budget request, the "Total Environmental Sustainability" budget makes nearly one quarter of the RE&D portfolio. Why does FAA believe environmental research should be conducted by FAA, when 13 other federal agencies fund climate research, instead of using those funds to improve safety? Do you believe FAA is the best agency in the federal government to conduct environmental research?

RESPONSE:

The primary environmental and energy issues facing aviation are aircraft noise, air quality, climate, energy, and water quality. Major strides in lessening the environmental effects of aviation have been made over the past several decades. However, aircraft noise continues to be the public's primary objection to near-term aviation growth. Aircraft emissions contribute to air quality-related health effects and climate change, as do emissions from all combustion processes. Noise and emissions will be the principal environmental constraints on the National Airspace System unless they are effectively managed and mitigated.

The environmental and energy challenges confronting aviation are not amenable to a single solution; rather, they will require multiple solutions involving technology, operations, and planning. Under the auspices of the Next Generation Air Transportation System (NextGen), the FAA is using its environmental research funds to implement a five-pillar strategy to address aviation environmental and energy issues through the following elements:

- Aircraft and Engine Technology Maturation
- Air Traffic Management and Operational Concept Improvements
- Alternative Jet Fuels Development
- Policies, Standards, and Measures Development
- Improved Scientific Understanding, Model Development and System Analysis

In response to Section 912 of the FAA Modernization and Reform Act of 2012, the FAA entered into an arrangement for an independent external review of FAA's energy-related and environment-related research programs. The independent panel reviewed the research programs, objectives, coordination of the research with other agencies, the allocation of resources, and the mechanisms for transitioning research results. The panel reported favorably on all areas, while expressing concern about future research funding levels and noting room for improvement in the transitioning of research. The FAA is taking steps to improve research transition mechanisms, considering the guidance offered by the panel. Administrator Huerta submitted the report to the House Committee on Science, Space, and Technology on July 18, 2013.

The FAA understands that there are other agencies involved in climate research. In FY 2015, we used only 1% of our environmental research program to fund climate related research. Our climate-related research is geared towards establishing a better understanding of any specific impacts from aviation operations, and identifying practical solutions to mitigate those impacts. The majority of the environmental research funds coming to the FAA go to the development of solutions to reduce aviation noise, emissions and fuel use. For example one of our major programs, the Continuous Lower Energy, Emissions and Noise Program (CLEEN) aims to mature and transition advanced airframe and engine technologies into the operating commercial fleet as quickly as possible to increase efficiency and reduce noise, emissions, and fuel use. FAA's role is vital as we work with industry to ensure solutions that are developed are safe to use in aircraft.

The FAA is uniquely suited to address issues on the noise and emissions created by commercial aviation. The FAA has a comprehensive plan to address the environmental challenges facing aviation in terms of noise, emissions, and energy use. The independent review conducted at the request of Congress of our environment R&D program reported favorably on our efforts. Therefore, we believe the FAA is indeed the best agency to conduct environmental research relating to aviation.

QUESTION #20: The Department of Transportation Inspector General announced in June that NextGen's developmental projects "do not have formally approved cost and schedule milestones and do not receive the program oversight given to other procurement programs." Why did the FAA choose to forgo cost and schedule milestones?

RESPONSE:

The FAA has a formal budget process that reviews all pre-implementation and implementation programs. This process establishes funding in support of the FAA's long-term plan as captured in the Enterprise Architecture (EA). The FAA Capital Investment Team (CIT), a team composed of representatives from budget, finance, and FAA executive leadership, assesses investment programs with comprehensive reviews based on cost, schedule, and performance of the pre-implementation investments to ensure alignment to FAA strategic goals. The CIT's findings are delivered to the FAA Joint Resource Council (JRC) which annually approves the EA and funding for all FAA programs.

The agency has an established internal control mechanism to ensure program oversight of pre-implementation activities. The FAA provides oversight of pre-implementation activities utilizing Project Level Agreements (PLA). These project agreements are used to ensure that all pre-implementation activities are executed in accordance with FAA policy. Project milestones, schedule, and deliverables are tracked by the FAA NAS Lifecycle Planning Division and regularly briefed to NextGen executive leadership. When pre-implementation activities progress further in development, they are reviewed by the FAA Enterprise

Architecture Board (EAB) to determine if they have sufficient merit to warrant inclusion in the Enterprise Architecture (EA). If the EAB endorses inclusion of the activity and the JRC approves its inclusion in the EA, the activity is subject to the Acquisition Management System process review moving from the Concept & Requirements Definition Readiness Decision through to the Final Investment Decision.

QUESTION #21: What recommendations do you have for R&D in the 2015 FAA reauthorization?

a) Do you have any recommendations regarding the UAS test sites?

RESPONSE:

We have no particular recommendations with respect to the UAS test sites at this point. However, we welcome the opportunity to address the broader question and would like to offer for the Committee's consideration the following:

Recognizing the considerable value that the FAA derives from the advice and counsel provided by the Research, Engineering and Development Advisory Committee (REDAC), we recommend that the language in 49 U.S. Code 44508 – Research Advisory Committee be maintained as is.

The dynamic nature of the aviation industry and the continuous emergence of new challenges necessitate increased agility and flexibility to conduct the research necessary to address those challenges. The present reprogramming authority cap—10% of the budget line item—limits the FAA's quick reaction flexibility and usually translates to a 3 year budget formulation delay before new high-impact research initiatives can be undertaken. Accordingly, the FAA would welcome increased budget reprogramming flexibility within its R,E&D portfolio so that it can quickly react and move to establish new program initiatives or augment existing ones as warranted by new findings, trends or events with significant system impact.

Based on analyses and recommendations provided by the REDAC we anticipate the need for increased emphasis and long-term research investment in the following thematic areas and technologies:

- Integration of UAS in the NAS
- Validation and Verification of Increasingly Complex NAS systems
- Human Factors of Increasingly Automated Systems
- Data Integrity and Cyber-Security
- Challenges and Opportunities of Big Data in the NAS
- General Aviation Safety

- Certification of Additive Manufacturing
- Electric Propulsion

QUESTION #22: After the alleged May hack of a United Airlines Boeing 737 system, has FAA changed its R,E&D strategy at all in regards to cybersecurity research?

RESPONSE:

Working with the FBI, DHS, and the manufacturer, the FAA has been unable to find any evidence to support the hacker's claims. No changes have been made to FAA's RE&D strategy as a result of this event.

QUESTION #23: Because of FAA regulation, researchers at U.S. universities are not permitted to research UAS without a Section 333 exemption and a COA, while researchers at many foreign universities are not restricted from performing such research. Do you think our regulations on research will put the U.S. at a disadvantage in regards to UAS?

RESPONSE:

Safety is our number one priority. Research may be conducted by universities under a Section 333 exemption or, for public universities conducting certain kinds of research, as public aircraft. The FAA has streamlined its process for issuing Section 333 exemptions and we regularly issue COAs to operators of public aircraft. The evaluations and conditions established through these processes help to ensure that these operations can be conducted safely.

QUESTION #24: Since 2008, Congress has provided more than \$1.5 billion in developmental projects intended to explore new concepts and evaluate alternatives to reduce uncertainty and risks associated with NextGen programs. However, unlike major acquisition programs, these projects do not have formally approved cost and schedule milestones and do not receive the program oversight given to other procurement programs. In lieu of cost, schedule, and performance milestones, how does the FAA ensure that these R&D programs are on budget and meeting their objectives?

- a) Without baseline cost, schedule, and performance metrics, how can Congress monitor progress on NextGen to ensure success?

RESPONSE:

Congress has provided more than \$1.5 billion in pre-implementation funding to explore new concepts and evaluate alternatives to reduce uncertainty and risks associated with NextGen programs since 2008. Pre-implementation dollars spent to date have led to successful Final Investment Decisions for programs such as Aeronautical Information Management (AIM) Segment 1 and AIM Segment 2, Automatic Dependent Surveillance-Broadcast (ADS-B), Common Support Services-Weather (CSS-Wx), Data Communications (Data Comm) Tower Services, National Airspace System (NAS) Voice System (NVS), NextGen Weather Processor (NWP), System Wide Information Management (SWIM), and Time Based Flow Management (TBFM) Work Package 3.

The FAA has a formal budget process that reviews all pre-implementation and implementation programs. This process establishes funding in support of the FAA's long term plan as captured in the Enterprise Architecture (EA). The FAA Capital Investment Team (CIT), a team composed of representatives from budget, finance, and FAA executive leadership, assesses investment programs with comprehensive reviews based on cost, schedule, and performance of the pre-implementation investments to ensure alignment to FAA strategic goals. The CIT's findings are delivered to the FAA Joint Resource Council (JRC) which annually approves the EA and funding for all FAA programs.

The FAA also has an established internal control mechanism to ensure program oversight of pre-implementation activities. The FAA provides oversight of pre-implementation activities utilizing Project Level Agreements (PLA). These project agreements are used to ensure that all pre-implementation activities are executed in accordance with FAA policy. Project milestones, schedule and deliverables are tracked by the FAA NAS Lifecycle Planning Division and regularly briefed to NextGen executive leadership. When pre-implementation activities progress further in development, they are reviewed by the FAA Enterprise Architecture Board (EAB) to determine if they have sufficient merit to warrant inclusion in the Enterprise Architecture (EA). If the EAB endorses inclusion of the activity and the JRC approves its inclusion in the EA, the activity is subject to the Acquisition Management System process review moving from the Concept & Requirements Definition Readiness Decision through to the Final Investment Decision. Examples of the efficacy of this internal control mechanism include upcoming Final Investment Decisions for programs such as Aeronautical Information Management (AIM) Segment 3, Collaborative Air Traffic Management (CATM) Work Package 4, Data Communications (Data Comm) Full En Route Services, and Terminal Flight Data Manager (TFDM).

Annually, the FAA documents the progress of pre-implementation work in the National Aviation Research Plan (NARP), NextGen Implementation Plan (NGIP), NextGen Update and the NextGen Performance Assessment. These resources document FAA progress toward NextGen and the benefits being delivered.

The NextGen Performance Snapshot (NPS) provides status on the NextGen Priorities Joint Implementation Plan, a joint FAA-aviation community effort, which was delivered to Congress in October 2014.

QUESTION #25: An annual survey conducted by IT firm CSC and the Aerospace Industries Association found that only 50 percent of the aerospace and defense industry are investing in R&D. What steps do you take to ensure FAA is not crowding-out private sector investment?

RESPONSE:

The FAA leverages the expertise, advice and counsel of the Research, Engineering and Development Advisory Committee (REDAC) to assist in determining that our R&D program initiatives are appropriate and complementary, rather than redundant, with private sector R&D. With a diverse membership consisting of representatives from varied sectors of the aviation industry including academia, aircraft manufacturers, and community specific consulting groups, this advisory group is well positioned to assess our research portfolio to determine how best to leverage private sector driven research initiatives. Indeed, the committee has occasionally pointed out proposed FAA research activity that is best left to private sector initiative.

QUESTION #26: UAS command and control technologies are vital to ensuring safe operation of UAS in the NAS. What is the current state of R&D on UAS command and control? What more needs to be done?

RESPONSE:

One of the most significant challenges to the safe integration of UAS in the NAS includes the development of reliable command and control (C2) capabilities within the unmanned aircraft, ground control station, and supporting NAS infrastructure. A primary goal of C2 research is the development of necessary standards governing C2 systems on both the unmanned aircraft and control station to ensure that the pilot always maintains a threshold level of control of the aircraft. Research will be conducted for UAS control data link communications to determine values for latency, availability, integrity, continuity, and other performance measures.

UAS contingency operation research evaluated the impact to air traffic controllers' work load in scenarios where UAS entered contingency modes of operation such as lost communications or lost control link. The findings from the research will help future efforts in defining controller procedures to cope with UAS contingencies upon integration of UAS into the NAS.

RTCA is developing technical standards for command and control to provide reliable link connectivity between the remote pilot controlling the aircraft from a ground control station

and the unmanned aircraft itself. The first phase of the technical standards development effort focuses on terrestrial communication systems operating in L and C bands of spectrum, which are more applicable to small UAS platforms. These standards will be drafted in 2015 and a one-year validation period is currently planned to mature the standards prior to their publication and use in type certified UAS.

FAA, NASA, and DoD are planning a number of research efforts to validate RTCA phase 1 technical standards and develop the supporting infrastructure for C2 to allow equipment employing these standards to be used in safe and efficient NAS operations. Further effort will be necessary as RTCA continues to develop additional standards for C2 capabilities in the second phase of its technical standards development activities, which will cover SATCOM and multiple bands of spectrum.

QUESTION #27: What are the barriers for university researchers who want to conduct UAS research? Is there any reason that researchers should NOT be allowed an exemption for operations that hobbyists currently enjoy?

RESPONSE:

University researchers may apply for a Section 333 exemption to operate a UAS. The FAA has streamlined its process for issuing 333 exemptions and has significantly increased the rate at which we are authorizing commercial UAS operations.

Researchers at public universities may also be eligible to conduct UAS research under the public aircraft statute (49 U.S.C. § 40125). Under this statute a public aircraft operation must be conducted using a public aircraft for one of the governmental functions identified in the law.

The FAA is using these processes to ensure the safety of the NAS and people and property on the ground.

QUESTION #28: How will the Center of Excellence (COE) for Unmanned Aircraft Systems help to integrate UAS into the NAS?

- a) How will FAA measure whether or not this COE is successful and a wise use of taxpayer's funds?

RESPONSE:

After a rigorous competition, the FAA selected a team led by Mississippi State University as the FAA's Center of Excellence for Unmanned Aircraft Systems (COE UAS). The COE will focus on research, education and training in areas critical to the safe and successful integration of UAS into the nation's airspace.

The team brings together 15 of the nation's leading UAS and aviation universities that have a proven commitment to UAS research and development and the necessary resources to provide the matching contribution to the government's investment.

The COE research areas are expected to evolve over time, but initially will include: detect and avoid technology; low-altitude operations safety; control and communications; spectrum management; human factors; compatibility with air traffic control operations; and training and certification of UAS pilots and other crewmembers, in addition to other areas.

- a) Congress mandated that the FAA establish the COE under the Consolidated Appropriations Act of 2014. Like university think tank partnerships, the agency's Centers of Excellence bring together the best minds in the nation to conduct research to educate, train and work with the FAA toward solutions for aviation-related challenges.

The COE is required to report progress on a quarterly basis which will be evaluated by FAA program managers to ensure that results align with defined research requirements and funding investment.

QUESTION #29: Please explain in detail FAA's vision for the Cybersecurity Test Facility (CYtC).

- a) How much total funding will CYtC receive in FY15, and what will those funds be used for?
- b) How many employees work on CYtC?
- c) How much funding would CYtC receive under the FY16 Presidential Budget Request, and what would those funds be used for?
- d) How will CYtC help protect ATC, airliners, UAS, and the NextGen Air Transportation System?
- e) How does CYtC coordinate with other federal agencies, including NSF, NIST, and DoD?

RESPONSE:

Under the Federal Information Security Management Act of 2002 (FISMA), Office of Management and Budget (OMB) Circular A-130, Management of Federal Information Resources, the FAA must identify and provide information security protection commensurate with the risk and magnitude of potential harm that could result from unauthorized access, use, disruption, modification, or destruction of information that supports the agency, aviation safety and security, and the National Airspace System (NAS). Furthermore, Cyber-attacks against Critical Infrastructure (CI) are growing. The sophistication of these attacks are also significantly increasing making it more and more likely that cyber-incidents will disrupt aviation networks. The FAA is standing up the Cybersecurity Test Facility (CyTF) to

proactively perform security evaluations and integrated testing of NAS systems, security products, and security services to reduce cyber exploitation and protect the NAS. The CyTF supports the requirements of OMB, Homeland Security Presidential Directives (HSPDs), as well as FISMA to ensure the security of FAA operational systems. To protect NAS systems against cyber-attacks, CyTF will be used to conduct advanced cyber research, evaluate proposed security solutions, and perform enterprise level integration security testing to ensure cyber solution feasibility and compatibility with NAS practices.

- a) The NAS Systems Engineering & Integration Office (ANG-B) is anticipating receiving \$1,538,463 from the Information Security & Privacy Service Office (AIS-1) in FY15. The funding will be used to improve FAA's integrated test capability by continuing to develop the CyTF cyber range and conducting cybersecurity exercises; to test and evaluate DHS Continuous Diagnostic Mitigation (CDM) capabilities for potential use in the NAS environment; and to conduct joint cyber exercises.
- b) Currently six FTE government and three FTE contractor staff work on CyTF. The CyTF support staff is adjusted with additional workers or assigned program support according to the needs of the specific evaluations and tests being conducted.
- c) Under the FY 2016 Presidential Budget Request, NPN/CyTF will receive 1.3 million to plan, develop, test, integrate, implement ISS technology to protect the FAA systems and networks against increased malicious activity, accidental or intentional, by insiders and outsiders; to implement Continuous Diagnostics and Mitigation (CDM) capabilities to continuously enhance the ability to prevent, deter, detect and respond to cyber-attacks against the FAA's infrastructure, and to improve enterprise ISS testing of air traffic control and NAS support systems.
- d) The CyTF provides advanced security research, evaluation, integrated testing services and capabilities to verify and validate proposed cyber solutions for NextGen/NAS applicability and deployment. Current major initiatives for the CyTF include implementation of the Continuous Diagnostic Mitigation (CDM) capabilities and policy in the NextGen Research & Development domain, testing of NAS system to validate security requirements, and development of intrusion and detection services to improve and protect NextGen/NAS security. It is envisioned that the CyTF will be used to support enterprise-wide cyber-attack simulation experiments to identify and evaluate security vulnerabilities and impacts on UAS command & control systems and aircraft avionics to address potential security control vulnerabilities that threaten the aviation domain. It is also the vision that the CyTF will be utilized to conduct cybersecurity incident response training to validate Incident Response Plans and improve the resiliency of the NAS.

- e) The NextGen Enterprise Safety and Information Security Division has actively been sharing information with all aviation stakeholders including NIST, DoD, DHS and A-ISAC (Aviation Information Sharing and Analysis Center). Through the NextGen Interagency Program Office, the CyTF identifies focused research areas and joint activities to be conducted with multiagency partners (DoD, DHS, NIST and NASA) such as participation in cyber exercises and development of the NAS cyber architecture and requirements to improve aviation security.

**HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
SUBCOMMITTEE ON SPACE**

“Transforming America’s Air Travel”

Mr. Dennis Filler, Director, William J. Hughes Technical Center, FAA

Questions submitted by Rep. Donna Edwards, Ranking Member, Space Subcommittee

QUESTION #1: To what extent is the NextGen Office carrying out responsibilities formerly assigned to the Joint Planning and Development Office (JPDO)? For example, how is the NextGen Office striking an appropriate balance between near-term and long-term planning, such as ensuring that future user benefits are still being considered despite the current emphasis on near-term airline benefits?

RESPONSE:

As part of the Consolidated Appropriations Act of 2014, Congress reassigned the responsibilities of the JPDO to the FAA’s NextGen Office. In response, the FAA created the Interagency Planning Office (IPO), a new directorate within the FAA’s NextGen Office. One of the key focus areas for the IPO is the far-term timeframe (2025-2030) to ensure the National Airspace System (NAS) continues to grow and meet new demands. As a multi-agency office, the IPO works hand-in-hand with government partners (including the Departments of Defense, Homeland Security, and NASA, as well as the National Weather Service) to collaboratively develop integrated plans, facilitate the transfer of technology, and identify and recommend research and development. In order to ensure near- and far-term planning is appropriately linked, the results of shared research initiatives among the NextGen partner agencies will be incorporated into the FAA’s NAS Enterprise Architecture to ensure the air transportation system keeps pace with evolving needs and technology after current plans for NextGen have been implemented.

QUESTION #2: Following successful demonstration at the Dallas-Ft. Worth International Airport, NASA "handed-off" the Precision Departure Release Capability (PDRC) tool to FAA in 2013.

- a) What is the status of FAA's implementation of PDRC?
- b) How challenging is it for FAA to transition tools such as PDRC into operational use?
- c) What, if anything, would facilitate such transitions in the future?

RESPONSE:

- a) NextGen worked with NASA to successfully transfer PDRC to the Air Traffic Organization Project Management Office (PMO) and the Terminal Flight Data Manager (TFDM) program team in August of 2013. This was accomplished through the Integrated

Arrival/Departure/Surface (IADS) Research Transition Team (RTT) process. Through the IADS RTT, NextGen was able to influence NASA's activities and include cooperation with the PMO to ensure high quality deliverables were created to enable direct transition of these products from NASA to the PMO for use in the Time Based Flow Management (TBFM)/TFDM programs. PDRC artifacts were used as requirements input for TBFM/TFDM Integration and to support the benefits case for TFDM investment decisions. The TFDM program is scheduled for a Final Investment Decision (FID) in spring 2016. With a successful FID, the required capabilities would begin to be deployed in the 2020 timeframe.

- b) The PDRC transfer was completed through the Integrated Arrival/Departure/Surface (IADS) Research Transition Team (RTT). The RTT's were formed for collaboration between FAA and NASA to link researchers and implementers earlier in the development lifecycle with the intent of creating harmonized deliverables, or Research Transition Products (RTPs). NextGen is the lead organization for the FAA in the RTT process. The PDRC RTPs were coordinated with respect to product and timing for TFDM investment decisions. Due to the highly cooperative nature of the RTT process, the FAA was able to influence the products, their content, and structure to enable them to either be directly used to support the FAA AMS process, or to serve as the baseline document for the PMO to further expand upon with FAA operational knowledge and insight.

This RTT transition process was further refined and strengthened during the Terminal Sequencing and Spacing (TSS) effort. The Efficient Flow into Congested Airspace (EFICA) RTT was formed to provide oversight and guidance of the TSS effort. With NextGen as the lead FAA organization, the FAA was able to delve deeper into NASA's Airspace Technology Demonstration-1 (ATD-1) project (the NASA project name for the FAA's TSS effort) than ever before. The FAA was not only able to influence the products, but we were able to integrate our program team into NASA's efforts. This allowed us to cooperatively develop nearly all aspects of the program, including but not limited to project plans, schedules, and Human-in-the-Loop (HITL) simulations. The FAA was key to obtaining operational controllers for a series of HITLs conducted to develop initial requirements for the PMO to use to finalize the requirements for TBFM Work Package 3. NextGen has been able to insert Flight Deck-Based Interval Management - Spacing (FIM-S) and Ground Based Interval Management - Spacing (GIM-S) requirements into the overall TSS/ATD-1 project. This capability is still being flushed out for implementation, but the RTT process has been so successful that the PMO inserted the TSS capability into the TBFM program, and considers it a key capability for the NAS.

- c) FAA and NASA have created additional Research Transition Teams to facilitate technical transfers in the future. The additional RTTs include Unmanned Autonomy, Data Management, Applied Traffic Flow Management and Weather Integration, and System Wide Safety Assurance. The Integrated Arrival/Departure/Surface and Efficient Flow into Congested Areas (EFICA) RTTs are continuing. Each of these RTTs are building onto the lessons learned from the other RTTs, and both NASA and the FAA are

aligning processes to ease the facilitation of future transfers in order to more effectively use the limited resources of both organizations, while maximizing the output of each.

QUESTION #3: The National Academies report on "Transformation in the Air--A Review of the FAA's Certification Research Plan" concluded that the FAA's Certification Research Plan was not responsive to Congressional direction for the plan.

- a) What are FAA's next steps in light of the report's recommendations? Will there be a formal response to the National Academies' report? If so, when?
- b) The National Academies report pointed out that the Plan only addressed certification for ground-based technologies and left out aircraft technologies. Why were aircraft technologies left out of the Plan?

RESPONSE:

- a) FAA does not plan on taking further action regarding the FAA's Certification Research Plan. The report's recommendations, while not being specifically addressed in the narrowly focused research plan mandated by Congress, are captured by existing planning documents, policies, and procedures such as the comprehensive National Aviation Research Plan (NARP). The NARP ensures that FAA's research and development is well managed and fulfills national aviation priorities. That plan is complemented by other systems, processes and procedures, such as the Acquisition Management System to oversee capital investments and certification requirements to ensure all air traffic equipment used in the nation's airspace system meet stringent federal standards. Additionally, the FAA's Aviation Safety (AVS) organization has numerous documents (regulations, policy, and guidance) which govern aircraft and flight deck avionics, procedures, and training which are designed to ensure we have one of the safest aviation systems in the world. The FAA met informally with NRC to discuss their findings and does not plan to formally respond to the National Academies' report.
- b) Another section in the FAA Modernization and Reform Act of 2012, section 312, asked the FAA to conduct an assessment of aircraft certification and approval processes, and make recommendations to improve efficiency and reduce costs. The FAA brought together industry experts in the Aircraft Certification Process Review and Reform Aviation Rulemaking Committee (ARC) to get input from the aviation community. We were evaluating the ARC's recommendations and determining implementation at the time our response to section 905 was written. The FAA has since developed a detailed implementation plan as a response to section 312, and has already initiated many activities as part of on-going, continuous certification process improvement efforts which are associated with the committee's recommendations. Details and updates can be found at this website:
http://www.faa.gov/regulations_policies/rulemaking/committees/documents/index.cfm/committee/browse/committeeID/137.

QUESTION #4: How is FAA utilizing NASA research to inform potential rulemaking on sonic boom for supersonic aircraft? Is there a timetable for rulemaking in this area? What, if any, other barriers need to be addressed to facilitate commercial supersonic air travel?

RESPONSE:

The FAA and NASA are working together on the research needed to consider the potential to allow civil supersonic aircraft over land in the United States. Currently, civil supersonic flight over land is not allowed in the United States under 14 CFR § 91.817. When considering civil supersonic aircraft, FAA is conducting work both domestically and internationally and NASA research is supporting both efforts. Domestically, FAA and NASA are working to ensure that the planned research in supersonics is complementary of each other. NASA is planning a low-boom flight demonstration and, if that demonstrator is built, the data created through community overflight testing will be evaluated to determine if further consideration of changes to 14 CFR § 91.817 is warranted, which may lead to rulemaking including a public notice and comment period.

Because any civil supersonic aircraft would have an international market, FAA is embarking on the creation of a noise certification scheme within the International Civil Aviation Organization's (ICAO) Committee on Aviation Environmental Protection (CAEP). NASA is a partner with the FAA in the ICAO CAEP work. NASA sonic boom response research from laboratory and flight simulations is being used in the early development of metrics and procedures to be included in a future noise certification scheme.

Domestic rulemaking activity is not expected to start until an agreement is reached within ICAO CAEP. The re-consideration of possible operating rule changes cannot happen until FAA has the necessary data, including low boom noise measurements from a full-scale demonstrator. FAA is relying on NASA research programs to provide the demonstrator and data. Given the technical and resourcing complexities involved, FAA believes any potential rulemaking would not happen until 2022 at the earliest.

The aforementioned data gathering is not currently within the scope of FAA work, but needs to be brought forward by NASA and industry participants. FAA does not see a path forward without data created from a low boom flight demonstration. In addition to overland supersonic flight requirements, FAA needs to consider any changes to the airworthiness requirements for civil supersonic aircraft. Finally, once we better understand the operating conditions of a future civil supersonic aircraft, then we will need to assess whether any air traffic procedural changes are necessary to ensure safe and efficient operations to and from the airport environs to the desired en route cruise altitudes.

QUESTION #5: In response to a question from Congressman LoBiondo on cybersecurity, you said that FAA was "actually turning the entire Technical Center into a cyber threat facility where we can attack each of our representative systems with various threats to be able to find out how our systems respond and then what countermeasures we have to develop and put into our system". Under what National Aviation Research Plan (NARP) activity is this research being conducted, what operational FAA "representative" systems have been or will be "attacked", what is the annual level of funding associated with this effort, and is there a documented plan or strategy driving this cybersecurity research activity?

RESPONSE:

There is no NARP activity presently associated with this initiative at this time. This effort is principally in support of Facilities and Engineering (F&E) and Operations activities. It does, however, leverage RE&D components and resources within our laboratories. A mature system engineering program requires advanced knowledge of dynamic and persistent cyber threats and corresponding systems vulnerabilities. We saw an opportunity to begin to implement a recommendation made by the FAA Research Engineering and Development Advisory Committee (REDAC) to the FAA in November 2014 to begin to explore NAS cyber security as a research area. During FY15, only \$115k of RE&D laboratory funds have been used to support this effort. A total of \$1.55 million of FAA Information System Security (ISS) (Non R&D) funds have been allocated for this activity. Having a Technical Center that houses almost one of every system in the NAS in its various forms, it was logical to use our operationally safe environment to create a capability to probe and understand system vulnerabilities in the presence of these threats. The multipurpose role of the Center and its vast array of NAS RE&D/T&E laboratories is an ideal facility to conduct this type of activity that crosses research, systems development, and operations domains. The goal of this activity is to leverage NIST, DHS and DoD capabilities and apply them to NAS systems where and when it is operationally feasible to do so. As this capability matures we envision that the program offices will use this capability to verify and enhance their system resiliency. As capability is amassed and expertise developed as to how to apply these leading edge tools and capabilities that we are receiving from our DHS and our DoD partners through our NextGen Interagency Program Office, (IPO), we will work with FAA program offices to develop plans to test systems to continue, as well as enhance, our ability to protect the NAS from cyber threats. We will continue our internal efforts to expand our cyber research initiatives within the FAA.

Responses by Mr. William Leber

**HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
SUBCOMMITTEE ON SPACE**

“Transforming America’s Air Travel”

Mr. William Leber, Co-Chair, Committee to Review the Federal Aviation Administration Research Plan on Certification of New Technologies into the National Airspace System; Vice-President, Air Traffic Innovations, PASSUR Aerospace

Questions submitted by Rep. Brian Babin, Chairman, Space Subcommittee

1. Your report highlights the importance of incorporating cybersecurity early in program development and in many research plans. Is FAA doing enough in this regard?

It is difficult to ever say what is “enough” when it comes to cybersecurity. The subject requires constant diligence because the persons trying to hack various systems never sleep. Our report highlighted this subject because it is so important, not because we detected any specific deficiencies on FAA’s part. Our study did not delve into that issue, but others have and they understand the subject much better.

2. If Congress were to mandate that FAA develop the “comprehensive research plan” recommended in the National Research Council (NRC) report, what should Congress direct FAA to include in that report? What are the characteristics of a well-designed comprehensive research plan?

Our report highlighted a number of them, but we singled out software assurance issues, cybersecurity, and verification and validation. We also suggested that FAA needed to look to other organizations and see what works best for them and determine if they can be applied to the FAA’s mission. It is common within the FAA to believe that what they do is so unique that there are no analogues in other organizations. But that is a mistake, because the activities of the FAA are so broad ranging that some of them are replicated by other organizations (in other words, not everything that FAA does is unique), and FAA personnel need to be open-minded and recognize that other organizations also strive for excellence and might have lessons the FAA can learn from.

- a. In writing a comprehensive research plan, what steps should FAA take to address the deficiencies the NRC report identified?

The committee noted in its report that a research plan is only a start. Writing a comprehensive research plan would itself address a deficiency. But the FAA has received other advice from other organizations.

3. What recommendations do you have for R&D in the 2015 FAA reauthorization?
 - a. Do you have any recommendations regarding UAS test sites?

This was beyond our committee’s charge. We did note that a lot of relevant R&D is conducted outside of the FAA, so my personal suggestion is that any reauthorization look at the broad picture of relevant R&D, not simply that performed within the FAA itself.

4. Because of FAA regulation, researchers at U.S. universities are not permitted to research UAS without a Section 333 exemption and a COA, while researchers at many foreign universities are not restricted from performing such research. Do you think our regulations on research will put the U.S. at a disadvantage in regards to UAS?

Our study did not look at that issue. A person who may be able to address these issues is Dr. Ella Atkins at the University of Michigan.

5. What is your opinion of FAA's Cybersecurity Test Facility (CYtC)?
 - a. Is there anything CYtC should be doing but isn't?

The committee did not perform a review of the facility or discuss it in any detail. It was outside of our charge.

**HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
SUBCOMMITTEE ON SPACE**

“Transforming America’s Air Travel”

Mr. William Leber, Co-Chair, Committee to Review the Federal Aviation Administration Research Plan on Certification of New Technologies into the National Airspace System; Vice-President, Air Traffic Innovations, PASSUR Aerospace

Questions submitted by Rep. Donna Edwards, Ranking Member, Space Subcommittee

1. In your prepared statement you indicated that the FAA’s certification research plan that your committee reviewed “omitted any substantive discussion of the air segment”, although “the FAA does provide a rationale for this omission”. However, the National Academies Committee’s report says:

“Committee discussions with FAA representatives revealed that aircraft systems were omitted from the February 2014 Research Plan at the direction of FAA management. No explanation was provided for this decision”

Can you clarify what appear to be contradictory statements? What was FAA’s rationale?

The committee was not provided with a rationale during its deliberations. After we presented our report to the FAA, we were informed that the section of The FAA Modernization and Reform Act of 2012 that called for the FAA to develop a research plan for the certification of new technologies dealt with ground systems, not air systems, so FAA confined their research plan to ground systems. The committee stands by its conclusion that a comprehensive plan has to address both air and ground elements.

2. Why is a comprehensive research plan that documents FAA’s approach for its certification and implementation procedures for NextGen ground and air elements into the National Airspace System important, and what are the implications of not having that plan at this time? How does the lack of a comprehensive plan impact progress on realizing benefits of NextGen?

We believe that establishing a research plan would help to focus and organize the FAA’s activities, and help it to identify what is within the FAA’s direct control, and what is not within the FAA’s direct control, and how those things may affect the timeline for implementing NextGen ground and air elements. A comprehensive research plan would help the FAA build greater confidence across the industry in both safety and efficiency aspects of NextGen and do a better job of identifying research gaps in the FAA’s own plans to implement NextGen in the most timely manner possible.

3. During the hearing, in response to my question on providing a perspective on prioritizing R&D areas, you mentioned that FAA has a cultural and communications challenge as opposed to a technical challenge. How should FAA address this issue?

Some of the ways to address that challenge are in our report. For example, looking to other agencies and organizations and determining their best practices and how they may apply to some of the FAA's own missions. The FAA communicates with many other parties in its operational duties. But we believe that it can communicate and possibly even coordinate, but certainly learn, from other organizations.

Responses by Dr. R. John Hansman

**HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
SUBCOMMITTEE ON SPACE**

“Transforming America’s Air Travel”

Questions for the record, Dr. R. John Hansman., Wilson Professor of Aeronautics & Astronautics, Massachusetts Institute of Technology; Director, MIT International Center for Air Transportation, Massachusetts Institute of Technology; Chair, FAA Research and Development Advisory Committee

Questions submitted by Rep. Brian Babin, Chairman, Space Subcommittee

1. What are the critical areas of civil aeronautics R&D that need to be addressed?

Critical areas include the impact of new electronic technologies (e.g. portable devices) on the safety and efficiency of air transportation, alternatives to leaded gasoline for high compression general aviation aircraft, safe integration of Unmanned Air Vehicles in civil airspace, particularly in the integration of manned and unmanned aircraft and reducing the environmental impact of aviation. There are also significant opportunities to use “big data” analysis techniques to identify opportunities to improve the efficiency and safety of the system. Another area of significant concern is the cyber security of the NAS and air transportation operations. Finally we need to find ways to stimulate innovation an interest of the upcoming generation of aerospace engineers, pilots and operators.

We also need to better address the system safety analysis approaches to allow more rapid adoption of new technologies and operating methods in a more efficient way

a. What long-term civil aeronautics R&D priorities are not addressed by the fiscal year 2016 budget request?

I have some concerns that we are not addressing the human factors which will emerge with the propagation of portable devices into cockpits. This will happen and I am not sure we fully understand all the issues. The integration of UAS into the NAS particularly in the areas of low altitude beyond line of sight (BLOS) and full UAS manned aircraft integration does not appear to be resourced at the level which will support the need.

2. How can R&D inform the feasibility, benefits, challenges, and opportunities associated with the privatization of the National Air Traffic Control System?

This appears to be more of a policy issue than a technology issue. However it is likely that there is baseline research on systems impacts and evaluation of best practices related to privatization in other states around the world. However it will be important to understand the unique requirements of the US system due to its traffic density and scale.

3. How should civil aeronautics R&D investments be divided and coordinated across

agencies?

NASA should be stimulating innovation and the generation of new approaches and ideas as well as developing baseline technology which will support the FAA in implementing improvements in the system. FAA should support R&D investments which support system improvement, as well as emerging safety, operational, congestion and environmental issues which can be anticipated to emerge in the mid term.

Bridges should be build to support the connection between DOD R&D and the emerging FAA needs. In particular taking advantage of the DOD experience in UAS can help define requirement for future civil UAS systems.

a. What inefficiencies exist in the current system and how could they be improved?

There are significant inefficiencies in flight trajectories due to the structure of the Air Traffic System which could be improved with better procedures and airspace design. Improvements are hampered by secondary issues such as environmental impact issues and safety analysis.

There are also cost inefficiencies due to the highly manual approach to ATC which exists around the world. There are opportunities to improve the cost efficiency through automation and facility consolidation although these have significant policy and safety concerns.

4. Because of FAA regulation, researchers at U.S. universities are not permitted to research UAS without a Section 333 exemption and a COA, while researchers at many foreign universities are not restricted from performing such research. Do you think our regulations on research will put the U.S. at a disadvantage in regards to UAS?

This is already a significant issue and concern. Colleagues in foreign universities in countries such as Australia have a much easier path to innovate in the UAS space than my colleagues in the US.

5. What are the barriers for university researchers who want to conduct UAS research? Is there any reason that researchers should NOT be allowed an exemption for operations that hobbyists currently enjoy?

There are no differences that I can see other than there is a higher degree of accountability and responsibility in the university research context than in the hobbyist context.

6. How has the distributed nature of FAA research activities impacted your ability to evaluate the effectiveness of the enterprise?

As I stated in my prepared remarks, it has been a challenge for the REDAC to maintain a comprehensive strategic view of the FAA research portfolio as research, engineering and development activities occur under different budget

accounts and offices including: RE&D, Facilities & Equipment, Operations (NextGen), and the Airport Trust Fund). The REDAC has a good process for being informed of research under the RE&D budget but less clear processes for the other budget lines.

**HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
SUBCOMMITTEE ON SPACE**

“Transforming America’s Air Travel”

Questions for the record, Dr. R. John Hansman., Wilson Professor of Aeronautics & Astronautics, Massachusetts Institute of Technology; Director, MIT International Center for Air Transportation, Massachusetts Institute of Technology; Chair, FAA Research and Development Advisory Committee

Questions submitted by Rep. Donna Edwards, Ranking Member, Space Subcommittee

1. What are the training and workforce issues associated with FAA research that you believe need to be addressed in the next 5 years? How is the agency ensuring that its workforce has the expertise necessary to tackle the emerging areas the REDAC has identified? What specific areas should FAA target for growing in-house expertise?

At a technical level the most difficult training and workforce issues are in the areas of operational information technology and cyber security. The national demand an opportunity for individuals who have background and experience in this area as well as opportunities in the “start up” economy make it a challenge for the FAA to attract a workforce with experience in these areas.

In addition there is a general demographic concern with the aging population of pilots, mechanics and aerospace engineers. In the pilot population this issue is exacerbated by increased minimum experience requirements for air carrier pilots coupled with the increased costs and barriers to gaining experience in the general aviation area. The anticipated shortfall of pilot and mechanics is a world wide issues and there is some concern that international opportunities for pilots and mechanics will make this problem worse.

In the areas of aeronautical engineering the core issues is the national STEM concern. We need to find opportunities to motivate students to build the core skills to be able to operate and improve our future air transportation system.

2. In your prepared statement, you call on FAA to conduct research to improve the noise evaluation process, support a strong scientific basis for any metric adjustments and enhance community involvement in noise abatement. Is the recently announced effort by FAA to survey residents around airports, by itself, responsive to the REDAC’s advice? What other research needs to be done?

The survey efforts are important but will not, on their own, be sufficient to enable improvements in the noise evaluation process. There is a need to develop better understanding of both the noise modeling but also the psychological and policy issues which will enable a rationalization of the noise evaluation process.

3. There have been proposals to privatize FAA’s air traffic control system. As Congress considers such proposals, do you have any concerns about their potential

impact on R&D or NextGen planning? If so, what are they?

I do have some concerns that in a privatization scenario the designated private Air Traffic Service Provider (ARSP) will be driven by short term needs and not have a longer term perspective of R&D needs or broader issues of public interest such as environmental impact of overall capacity improvement. It is not clear to me how the research agenda would be defined.

Responses by Dr. Greg Hyslop

**HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
SUBCOMMITTEE ON SPACE**

“Transforming America’s Air Travel”

Dr. Greg Hyslop, Senior Member, American Institute for Aeronautics and Astronautics; Vice President and General Manager, Boeing Research & Technology, the Boeing Company; Chief Engineer, Engineering, Operations & Technology, the Boeing Company

Questions submitted by Rep. Brian Babin, Chairman, Space Subcommittee

1. *Last month, the NRC issued a report titled “A Review of the Next Generation Transportation System: Implications and Importance of System Architecture.” This report found that “the original vision for NextGen is not what is being implemented today. Instead, NextGen today primarily emphasizes replacing and modernizing aging equipment and systems.” Do you agree with the NRC’s assessment? Why or why not?*

In answering this question, we first note that the FAA maintains and operates the safest transportation system in the nation, and indeed the entire world. It does this in spite of the system also being the most complex transportation system in the world. The conservatism inherent in its safe operation is firmly ingrained in the FAA’s culture. Many experts have observed that the historical dual roles of the FAA, to both encourage aerospace travel and to regulate aerospace travel, are contradictory. In fact, the regulatory role, especially as it relates to the safety of the flying public, has come to be the predominant, if not sole, role of the FAA. Therefore, when faced with the challenge of modernizing the air traffic management system, it is only natural that the system architecture, whatever its shortcoming may be, has been conceived and subsequently scrutinized from this safety perspective.

To transform the air traffic management system using 21st-century technologies—especially those centered around IT, communication, and automation capabilities—the FAA needs to approach all facets of NextGen with the rigor and passion it does with system safety. Whether it is the cybersecurity of the system, integration of UAS into the NAS, the human-machine interface, or the overall architecture, it is, as the NRC report so eloquently notes, unrealistic to expect system transformation.

The first recommendation in the report, exhorting stakeholders to reset their expectations, was the most cogent and realistic of all the report’s recommendations. So much so that one suspects that the myriad of recommendations regarding the system architecture capabilities and needs within the FAA will prove to be vexing, if not elusive. However, that is not to say that the majority of the report’s recommendations are to be taken lightly. In the aggregate, they describe a real problem that is endemic to the FAA’s capabilities and culture. A real question would seemingly be, what is the ability of the FAA to manage, assess, and implement, where appropriate, the R&D efforts that will be required to realize NextGen’s desired capabilities?

The recommendations regarding risk management and cost/benefit are well known to the FAA. So much of what the FAA aspires to do with regards to air traffic management modernization is based upon a projected steadily increasing and stressed air transportation system. Were this future scenario

to play out, aviation gridlock is an unacceptable path forward for this nation. Our economy is inextricably tied to an efficient air transportation system, for both passengers and cargo. The investments that the report rightfully acknowledges will be for the purposes of modernizing the system and will lead to incremental improvements, as opposed to the originally envisioned transformation; this is not a bad thing, perse. However, to start to achieve true transformation, an assured steady funding stream that includes sufficient R&D funding for the FAA and NASA, and for ATM system recapitalization, is as essential as creating the system architecture focused organization. Both will be necessary to field the NextGen technologies and systems that are essential to start to realize the efficient air traffic management system as was originally envisioned and that is not simply a replacement of existing capabilities, albeit with more modern technology, as the report bemoans.

2. *From an industry and professional society perspective, do you have any thoughts on how the R,E&D portfolio for NextGen should be allocated?*
 - a. *Are there activities that the private sector would like to see the government taking a more active role in?*
 - i. *Are there areas that duplicate private sector research?*

Fully 92.5 percent of the FAA's FY 2015 NextGen funding request profile was directed to Facilities & Equipment (\$774M of \$836M). The Research, Engineering & Development (R,E&D) request totaled just over 5 percent. The FAA's stated rationale was "to achieve NextGen goals that have the largest benefits and the biggest need by focusing the deployment on enhancements at 'optimal' sites and delivering ready capabilities now." We agree that this alignment will help to integrate functionalities for the user community, and that some of the proposed investments here are in fact the results of years of concerted R&D efforts by both the FAA and NASA, for example, separation management and multiple runway operations. However, in deploying upgrades now, the FAA is surely on a path to incremental modernization, as was a key point made in the recently released NRC report, and it will probably find it difficult to make transformational changes that take full advantage of R&D efforts and results.

The NextGen R,E&D focus areas of alternative fuels for GA aircraft, wake turbulence, air ground integration, weather in the cockpit, and environmental research, aircraft technologies, fuels and metrics seemingly have a nearer term focus of assured implementation of technologies that have been in the works within the R&D community for quite some time.

Our two most pressing recommendations then are not so much about the allocation of the R,E&D portfolio but how to best ensure that R&D results actually get a fair opportunity to move out of R&D and into field trials/implementation. They also address the question about an active government role, as both are government-appropriate activities. First, the institutionalization, and perhaps even codification, of the FAA-NASA Research Transition Teams is the most viable and practical tool available to ensure R&D results transition. Second, we have concerns about the seeming lack of priority of R,E&D funding to Advanced Systems and Software Verification and Validation and to the cybersecurity of these advanced NextGen systems. Without adequate tools, methodologies to address V&V and cybersecurity concerns will certainly jeopardize the successful fielding of any specific NextGen technology, if not the entire system. R&D efforts are necessary in these areas, as existing tools and methodologies will prove to be inadequate.

3. *If the federal government is investing in research that the U.S. private sector is also investing in, the federal government may be crowding out private sector investment and innovation. What should the government do to ensure that it's not competing with private sector research and development efforts?*

In fact, there are many industries and technologies in which the U.S. government and the private sector invest jointly to spur competitiveness in a global marketplace. One way of preventing unintended parallel efforts and limiting the government from crowding out private sector investment is to encourage public/private partnerships. This approach encourages all U.S. entities that would benefit from such investments and helps maximize the return on investment in respective technology sectors. It is a positive factor in today's business environment where R&D may not be necessarily plentiful. It is also important to have good communication about the government future interest areas to guide industry's future investment decisions without controlling decisions. Moreover, government must preserve industry's ability to direct their R&D investments (i.e. maintain the "independence" of IRAD). Otherwise government-directed R&D may actually reduce R&D spending, the opposite of the intended result.

Wearing my Boeing hat, a key company proof-point of the value of public-private R&D partnerships is our work with NASA on the ecoDemonstrator Program, which tests technologies to reduce aviation's environmental impact, such as CO₂ emissions and noise. NASA and FAA's CLEEN Program have been key partners in ecoDemonstrator testing of technologies that can improve the efficiency of airplanes and air traffic management. For example, Boeing just worked with NASA to test "bug-phobic" coatings on the wing of the ecoDemonstrator 757 to make flight more efficient. These technologies could provide aircraft operators with significant operational benefits, including the potential cost savings of reduced fuel consumption; could make a notable contribution to helping aviation reduce its carbon footprint, which would support the global aviation industry's pledge for zero-carbon growth by 2020; and could help enable U.S. companies to offer customers across the world technologies that provide the capabilities they demand.

4. *The Administration just announced that it intends to regulate aircraft emissions, despite the fact that the industry has increased the fuel efficiency of jetliners by 70 percent over the last 50 years. Given this track record, are regulations necessary for industry to reduce emissions?*

On 10 June 2015, the EPA, with input from the FAA, issued a draft endangerment finding that carbon emissions from commercial aviation contribute to atmospheric concentrations of greenhouse gases affecting climate change and require greater regulation by the U.S. government. This action was fully expected because, as the EPA states, the finding is a necessary step in the U.S. government process – coordinated by the EPA and the FAA – to support an expected CO₂ standard for aircraft. This standard is currently under negotiation in the United Nations' International Civil Aviation Organization (ICAO) and is expected to be adopted in late 2016. If ICAO fails to agree on a global standard, the EPA finding then would necessitate that the U.S. government enact its own standard.

The aviation industry has indeed made tremendous progress improving airplane efficiency and reducing airplane emissions (70 percent since the dawn of the jet age) and we are committed to doing more. We support the International Air Transport Association's emission reduction targets (carbon neutral by 2020 and a 50 percent reduction in emissions by 2050 when compared to 2005), and we support the effort underway at ICAO to establish a global standard for airplane emissions, which is expected to conclude sometime in 2016. What the EPA did with its draft endangerment finding is a necessary step toward eventual U.S. adoption of such a global standard, which is what we believe the EPA intends to do.

5. *What recommendations do you have for R&D in the 2015 FAA reauthorization?*

a. *Do you have any recommendations regarding the UAS test sites?*

With regards to recommendations for R&D priorities, I want to reiterate several points that I made in my testimony. First, it is vital that Congress continues to provide funds for long-lead research projects that lead to more efficient airframes and engines. We touched on research in this area in our answer to the Chairman's second question. Second, and perhaps more critical, would be reauthorization-specific language on R&D expenditures and initiatives that would assure that the FAA has a skilled and trained workforce, with the appropriate tools and methodologies, to keep up with and enable the pace of innovation occurring in the aerospace sector. One program designed to make maximal and optimal use of FAA resources is already under study. Government and industry have been involved in research and development necessary to move toward a systems engineering approach to airplane and engine certification. The end result of this research would be a better, more efficient certification process; one that encourages innovation and accelerates the incorporation of innovative product enhancements that make airplanes more efficient, safer, and more comfortable for passengers.

AIAA supports the UAS test sites and any R&D work that may be being performed at these sites. Our key recommendation with regards to the test sites is to ensure access and use by our nation's universities. Many faculty, staff, and students desire to fly and operate primarily small UAS for a variety of purposes, including student education, research and development, and student competitions. The ability of universities to do so, even in unrestricted Class G airspace, currently is limited by rules and restrictions as levied by the FAA. The success of universities to either obtain CoAs or Section 333 Exemptions or to gain affordable access to the approved test sites has been limited to date. The development and realization of UAS integration into the national airspace will surely be informed, in part, by contributions from researchers at universities. It is our understanding that the test site's authority is not restricted to specific geographical locations. By this we mean that universities could be provided with the option to conduct their experiments at either approved test sites or at their own, secure university-owned property. A viable path forward is to develop a clear and unambiguous approach for educational institutions to make optimal use of the UAS test site's authorities.

**HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
SUBCOMMITTEE ON SPACE**

“Transforming America’s Air Travel”

Dr. Greg Hyslop, Senior Member, American Institute for Aeronautics and Astronautics; Vice President and General Manager, Boeing Research & Technology, the Boeing Company; Chief Engineer, Engineering, Operations & Technology, the Boeing Company

Questions submitted by Rep. Donna Edwards, Ranking Member, Space Subcommittee

1. *In your prepared statement, you indicated that when we fail to invest in new R&D programs, we risk losing talent and expertise that has taken us decades to cultivate.*
 - a. *Are there any current impacts related to a lack of talent and expertise? If so, can you provide some examples?*
 - i. *You identify the need for challenging new projects. What are some examples of such projects? What will it take to realize such projects?*

The aerospace talent shortage in the United States is the result of a steady decline in engineering graduates, an unstable industrial base, and a lack of H1B visas being granted to foreign students being educated in our universities. Couple this with the fact that an overwhelming majority of the aerospace workforce is between the ages of 40 and 65, and there is an ongoing concern that industry will be unable to keep up with customer deliveries or be able to expand operations. It is also important to note that the International Traffic in Arms Regulations governs many of the aircraft, rockets, satellites, and missiles that aerospace and defense companies produce, which means many aerospace industry positions require a U.S. security clearance, thus disqualifying skilled foreign workers, many of whom were educated in the United States.

While there are presently no drastic or immediate impacts to U.S. industry related to this talent shortage, the slower pace at which aerospace defense acquisition and commercial product development is occurring could be both a symptom of this shortage while simultaneously masking its effect. Now is the time to take novel steps to recruit, train, and retain talent. Effective talent recruitment strategies involve collaboration among private sector, government, and educational institutions that target numerous talent-development issues including STEM education, relevant job skills training, and the recruitment/retention of the new talent necessary to spur innovation. Today’s young talent is drawn to the “next big thing,” so we must change the stereotype that the industry needs only aerospace engineers and instead recruit every flavor of engineer in the aerospace—from cybersecurity to biotechnology to communications and IT to materials scientists. We must also recruit from outside the industry to find the talent to meet the analytics needs.

Young people around the world are looking for the same thing—a career that challenges them, allows them to grow and reach their potential, and connects them to something greater than themselves. Students, and particularly women in engineering, report that they are actively seeking opportunities to do societal good. NASA science programs such as the Mars Science Laboratory and the New Horizons spacecraft (with its recent Pluto flyby) surely capture some student’s imaginations. And aircraft like the Boeing 787 and the Gulfstream 650 similarly do so for other students and young professionals. It is hoped that some R&D programs like the FAA’s CLEEN and CLEEN II projects and NASA’s Environmentally

Responsible Aviation and N+3 projects, with the objective of protecting the environment by reducing aviation's impacts while enabling the type of mobility that only aviation can provide, similarly appeal to and excite young women and men who look at aerospace as a profession and hope those aspirations can be fulfilled.

Lastly, we need great teachers, a rigorous curriculum that simultaneously challenges and excites students, and parental support to help inspire the next generation with big, bold ideas. We can attract tomorrow's engineers by capturing their imagination and letting them be part of an exciting mission that will shape the future and improve the lot of society and the planet. We think there are compelling missions for this and future generations, and we are confident that they will find the solutions to many societal needs, in aerospace as well as fields like healthcare, energy independence, and climate science.

2. *Your prepared statement noted that a more efficient certification process would encourage innovation. Mr. Leber testified on the National Academies review of the FAA's Certification Research Plan which recommended a comprehensive certification research plan. What are the potential benefits to industry of having such a comprehensive certification research plan that outlines the FAA's research goals and plans for integrating and certifying technology for use in the National Airspace System?*

While at a macro level the FAA has already implemented many improvement initiatives for certification process efficiencies and others are in progress, there is clearly room for further improvements to ensure competitive advancements within our aviation and manufacturing industries. It is our belief, shared by industry, that the FAA has not fully integrated these initiatives, overseen their implementation, measured their benefits, or clearly linked them to a future state. This is the best opportunity for leverage, looking forward.

While civil commercial transport manufacturers share many similar certification requirements and processes with civil general aviation manufacturers, there are differences in their direct lines of businesses stemming from the certification categorization, risk, and complexity of their respective systems. The success of commercial aviation manufacturers in the United States is dependent on the performance of the FAA. If the FAA is not efficient and effective, or does not have efficient and effective processes, that can put U.S. manufacturers at a competitive disadvantage relative to manufacturers in other countries from a cost and schedule performance perspective.

To this point and in collaboration with our industry associations, Aerospace Industries Association (AIA) and General Aviation Manufacturers Association (GAMA), U.S. industry has expressed concerns about the efficiency and effectiveness of the FAA. In response to those concerns, Congress included language in the FAA Modernization and Reform Act of 2012 directing the FAA to conduct an immediate study of FAA certification processes and their ability to support anticipated U.S. manufacturer certification activity.

The FAA chartered an Aviation Rulemaking Committee (ARC) specifically to make recommendations to improve efficiency and reduce costs through streamlining and reengineering the certification process to ensure that the FAA can conduct certifications and approvals in a manner that supports and enables the developments of new products and technologies and global competitiveness of the U.S. aviation industry. The ARC has completed its assessment and observed that there are many existing improvement initiatives for certification process efficiencies already implemented or that are in progress. However, the FAA has not fully integrated these initiatives, overseen their implementation, measured their benefits, or clearly linked them to a future state. Given these conclusions, the ARC developed specific recommendations around these known areas of inefficiencies and opportunities for further improvements. Those recommendations have been approved by the FAA and now have been submitted to Congress for their review and approval.

3. *There have been proposals to privatize FAA's air traffic control system. As Congress considers such proposals, do you have any concerns about their potential impact on R&D or NextGen planning? If so, what are they?*

From the 24 March 2015 House Subcommittee on Aviation hearing on this topic, it is our understanding that the privatization concept being considered would split the air traffic controllers and NextGen from FAA control and that the downsized FAA would retain responsibility for aviation safety regulations (gleaned from popular press articles on the subject). Shifting NextGen to a private concern would present daunting challenges, including infrastructure re-capitalization (hardware and software) and the ability to make adequate R&D investments. Generally private, or corporate, R&D in the aerospace industry is focused on product development, where technology advances are required in order to design and develop that next product. This should be the expected path that a private Air Traffic Management organization would follow. The vast majority of their discretionary funds would be allocated to re-capitalization of the existing system with precious few dollars for transformative technologies R&D. R&D that is focused on longer term solutions, or future generation technologies have largely been the purview of government organizations. Those being the DoD and NASA in the aerospace field, and the federal government would need to ensure that these organizations receive adequate funding to perform such R&D with the purpose of transforming air traffic.

Since the privatization model is ill-defined or at best in its formative stages, at this time, our concerns for NextGen planning and related R&D are shaped wholly by this existing uncertainty. Most assuredly, an FAA organization centered on safety would focus their R&D efforts on safety regulation related activities. This would leave any, and perhaps all, government-performed NextGen R&D to the NASA Aeronautics Program. The stress that such a scenario may place upon NASA, given the small percentage of the overall agency budget dedicated to Aeronautics Research, would be something to watch closely. Were NASA not appropriated funds at a level consistent with, or greater than the sum of current NASA and FAA NextGen R&D funding, one could easily envision a continuing challenge to develop truly transformative ATM technologies, which the proponents of a privatized air traffic management system seemingly favor.

Appendix II

ADDITIONAL MATERIAL FOR THE RECORD

PREPARED STATEMENT OF COMMITTEE RANKING MEMBER

EDDIE BERNICE JOHNSON

Thank you, Mr. Chairman, for holding this morning's hearing on "Transforming America's Air Travel" and welcome to the chairmanship of the Space Subcommittee. I look forward to what I hope will be a strong, bipartisan partnership on addressing the important space and aeronautics issues facing our nation.

Mr. Chairman, as Members of Congress we fly a lot, often weekly, between our Districts and Washington, D.C. Like millions of other Americans who travel on commercial airlines, we can appreciate the importance of our nation's strong safety record in civil aviation.

This record is the result of hard work and a steadfast commitment by the FAA and the civil aviation community to the safety of our nation's airspace system, and I commend them on their dedication. However, as a Member of both this Committee and the Transportation Committee, I know that the world of aviation is rapidly changing.

New technologies and capabilities, such as unmanned aircraft systems, present significant opportunities for economic growth. Yet they also present challenges in their safe integration into the national airspace system.

And, while the NextGen initiative is intended to enable our aviation system to respond to growing capacity, it too has its own challenges. Pilots and air traffic controllers will need to interact with new sources of information and increased use of automated systems that will require changes in how they make decisions.

In short, Mr. Chairman, the changes to our aviation system will not be simply technological, they will be cultural. Because it is people who are at the heart of safety, and the ongoing transformation of aviation in the U.S. will require not just research and development, but also an evolution of our workforce and the training that we provide to it.

I look forward to hearing from our witnesses on what is needed to foster the skills that our workforce will need in order to fulfill the potential of new capabilities while mitigating any risks that the transformation of our aviation system will involve.

In summary, Mr. Chairman, aviation and aeronautics research is vital to the well-being of this nation. We need to ensure that NASA and FAA have the resources they will need to continue to make progress in the coming years.

It is an investment that will pay dividends far into the future. Thank you, Mr. Chairman, and I yield back.

